Electrical Engineering

Registered U. S. Patent Office

for July 1939—

The Cover: A view in a crossbar dial-switching telephone plant. This new switching system, now being placed in operation on the Bell System, was described in the TRANSACTIONS section of the May issue, pages 179-92

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¶ Correspondence is invited on all controversial matters.

High Lights

Inductive Co-ordination. Introduction of the sodium-vapor lamp for highway lighting produces new problems of noise induction on telephone lines because of the wave-shape characteristics of the lamps. Co-ordination of the systems from the noise standpoint is necessary where series circuits supplying many such lamps are involved in exposures with open-wire telephone lines (*Transactions pages 325–32*).

Solar Energy. In discussing experiments on the utilization of the heat from the sun, a noted authority on this subject says that the State of New Mexico could supply from solar radiation more energy than is now obtained from all coal, oil, and water at present used annually for heat, light, and power combined in the United States (*pages 294–8*).

Polyphase Broadcasting. A system of amplitude-modulated radiobroadcasting that compares with present-day broadcasting much as a polyphase generator compares with a single-phase generator offers the possibility of reducing the capacity of the final power amplifier, for a given transmitter power rating, to half that now required (*Transactions pages 347–50*).

Conservators of Capital. "Literally no one can escape the personal effect from continued Government spending in excess of a level of tax earnings that is already up to about the limit that industry can carry," says a prominent engineer, who urges engineers, as natural conservators of capital, to "sound the alarm" (*pages 291–3*).

New AIEE Officers. Among other items of business at the annual meeting of the AIEE held during the combined summer and Pacific Coast convention just concluded in San Francisco, Calif., was the announcement of the election of new officers for the administrative year beginning August 1 (*page 301*).

District Meetings. Plans are actively in progress for two AIEE District meetings: one will be held September 27–29 by the Great Lakes District at Minneapolis, Minn. (*page 303*); the other October 11–13 by the Middle Eastern District at Scranton, Pa. (*pages 303–04*).

Directors Report. The annual report of the AIEE board of directors to the membership for the fiscal year ending April 30, 1939, is included in full in this issue. It contains brief reports of the various Institute committees and the usual financial tabulations (*pages 305–17*).

Carrier System. A carrier telephone system for open-wire lines that extends the frequency range from about 30 kilocycles, the highest previously used, to more than 140 kilocycles adds 12 more channels to the four already furnished by each pair of wires (*Transactions pages 351–60*).

Stray Load Loss. Experimental work indicates that determination of the stray load loss in induction machines by reverse-rotation test, in which the machine is driven at synchronous speed opposite to its normal direction of rotation, is simple and accurate (*Transactions pages 319–24*).

Electromagnetic Horns. Ultrahigh-frequency electromagnetic waves may be transmitted and received using flared horns of metal as antennas. Principles of design for sectoral and pyramidal horns are given in a paper in this issue (*Transactions pages 333–8*).

Social Obligations. Some thoughts on the social obligations of engineers expressed in an address by AIEE President John C. Parker at a recent District meeting may give other members food for thought (*pages 285–6*).

Highway Lighting. So-called "traffic safety lighting," which renders the road surfaces bright so that objects are seen in silhouette, is reducing automobile traffic fatalities markedly in cities where it has been applied (*pages 287–90*).

Gas-Filled Cables. Inert gas at pressures in the range from about 10 to 15 pounds per square inch is used as the pressure medium in a new high-voltage cable which, from an economic standpoint, may be used at 40 kv or less (*Transactions pages 307–18*).

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Cold-Cathode Tubes. Gas-filled tubes that require no cathode heating may be useful circuit elements where currents do not exceed 100 milliamperes. Functions include action as a relay, a rectifier, or a voltage regulator (*Transactions pages 342–7*).

Electric Drives. Supercalenders, which are used to give a high surface finish to paper, are examples of machines for which electric motors are required to provide unusual flexibility (*Transactions pages 338–41*).

Welder Control. Electronic timing control for resistance welders has been extended economically to small welders by a circuit employing recently developed types of cold-cathode tubes (*Transactions pages 361–4*).

Synchronous-Machine Calculations. A simplified method of calculating curves of terminal voltage versus field current for various overexcited power factors has been devised (*pages 299–300*).

Standards Subcommittee. Among the co-ordinating subcommittees recently appointed to broaden the standards work of the AIEE is one to co-ordinate reference values (*page 304*).

A-C Welding. Arc welding with alternating current has been improved by circuits that prevent the open-circuit voltage from rising to dangerous values (*Transactions pages 364–70*).

Coming Soon. Among special articles and technical papers now undergoing preparation for early publication are: an article describing the electrical features of the Union Pacific's new steam-electric locomotive; an article defining the unit "decibel" in simplified language, by H. P. Lawther (A'28); an article presenting simplified computations of voltage regulation, by R. D. Evans (M'26); an article describing a method for determining the efficiencies of small motors from the heat due to eddy currents, by J. L. C. Löf, current recipient of the AIEE national prize for Branch paper; a paper on multiple-grid circuit breakers by J. B. MacNeill (M'36) and A. W. Hill (A'38); papers describing air circuit breakers by L. R. Ludwig (A'28) and G. G. Grissinger (M'38), and R. C. Dickinson (A'37); a paper on power system transients caused by switching and faults by R. D. Evans (M'26), A. C. Monteith (A'25), and R. L. Witzke (A'37); a paper on power-system voltage-recovery characteristics by H. A. Peterson (A'35); a paper on the effect of restriking on recovery voltage by C. Concordia (M'37) and W. F. Skeats (M'36); a paper on the influence of resistance on switching transients by R. C. Van Sickle (M'37); and a paper on overvoltages during power-system faults by Edith Clarke (M'33), S. B. Crary (M'37), and H. A. Peterson (A'35).

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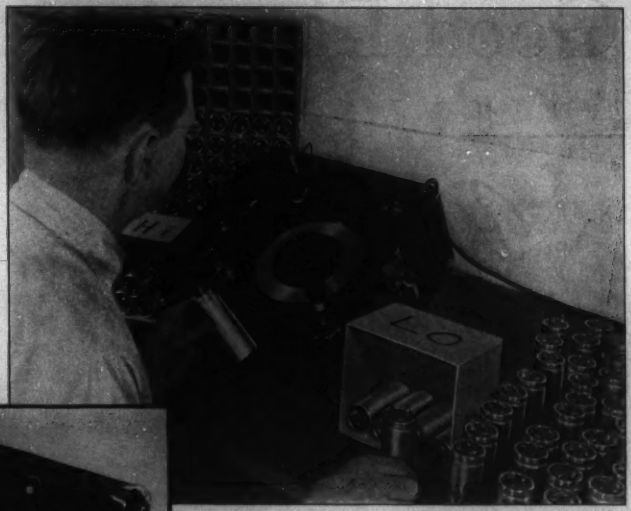

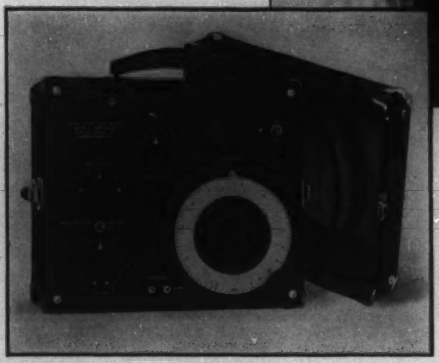

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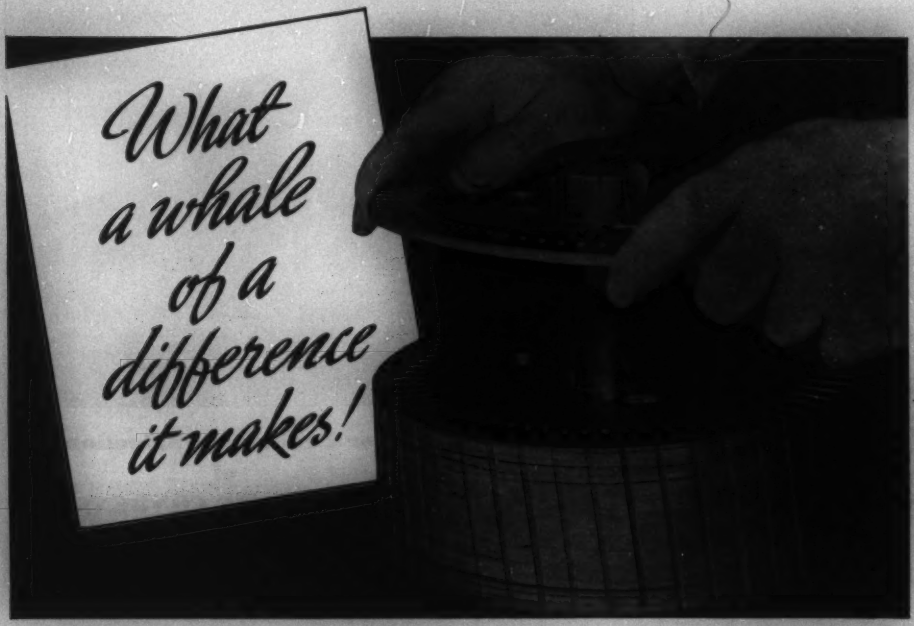

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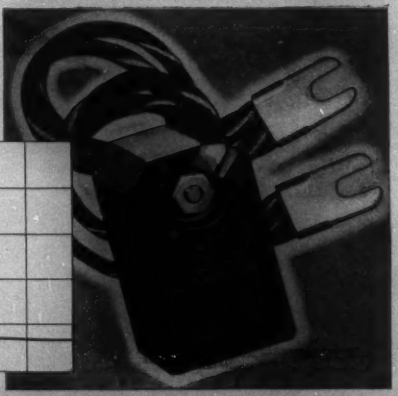

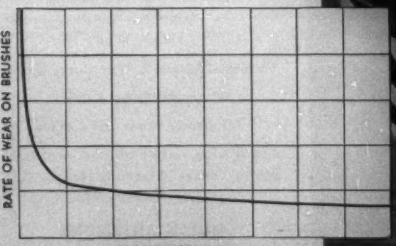

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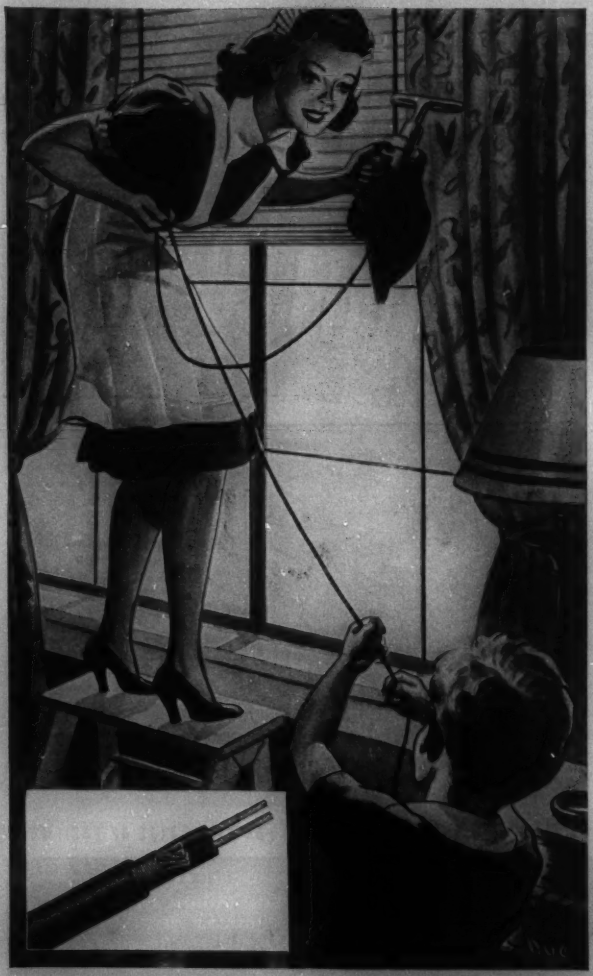

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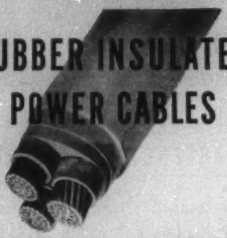

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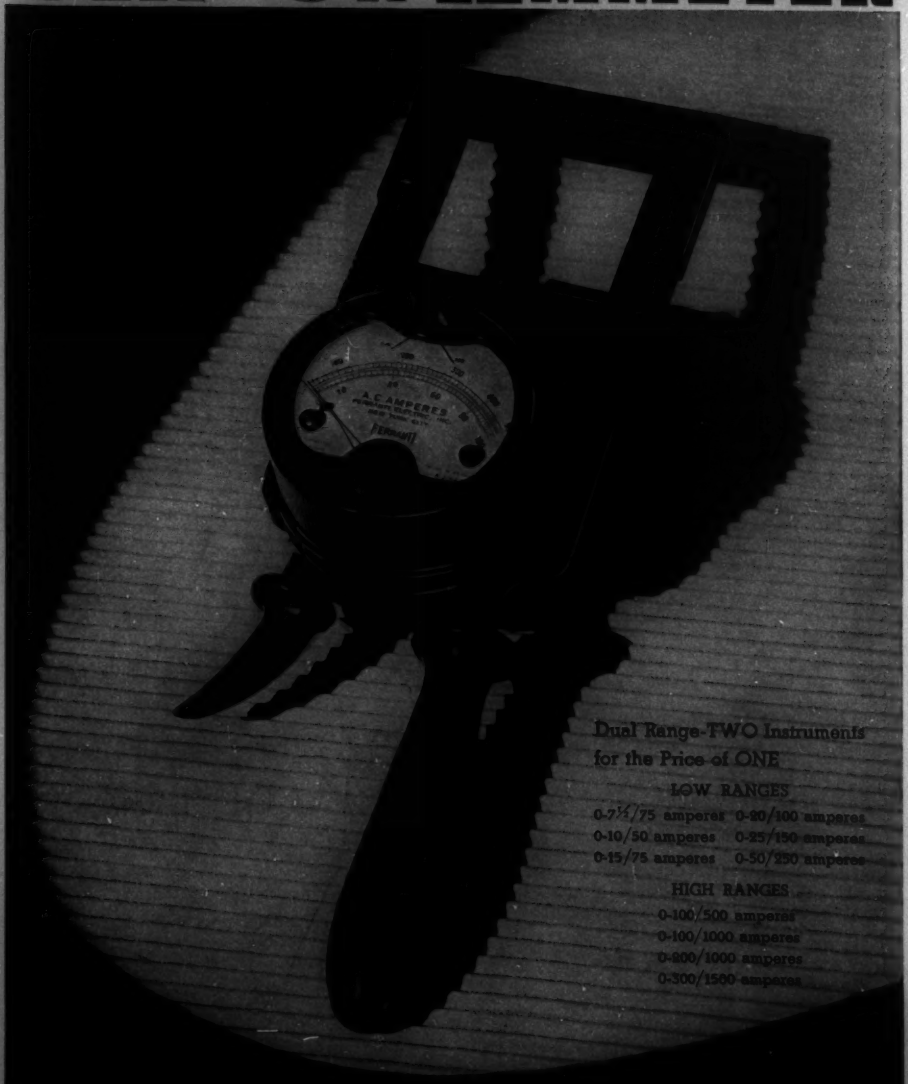

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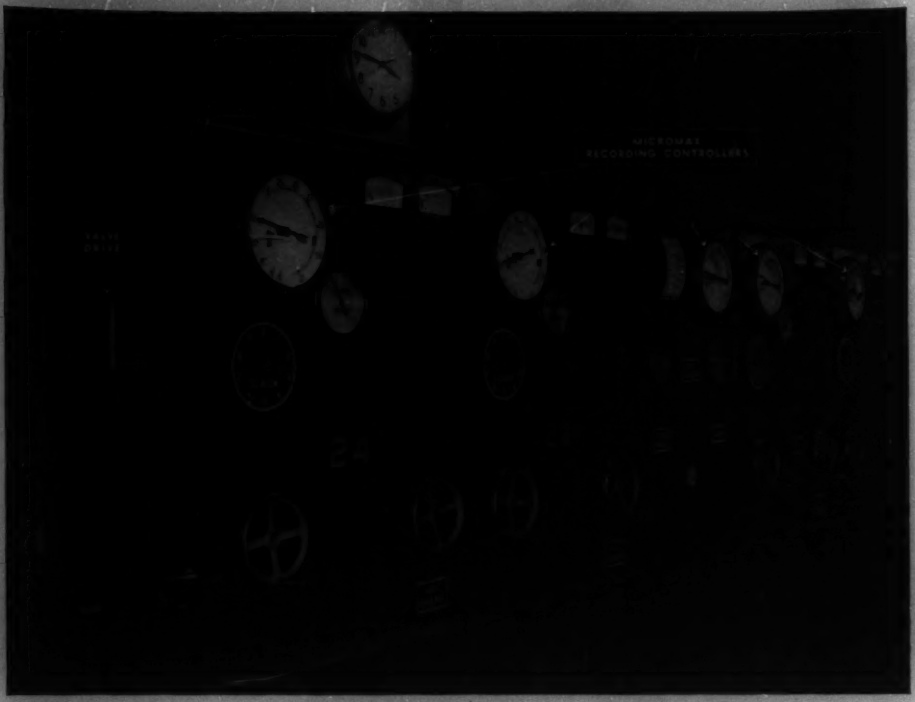

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Some Thoughts on the

Social Obligations of Engineers

JOHN C. PARKER
PRESIDENT AIEE

MEMBERS of the engineering profession are becoming increasingly sensitive to their social obligations both collectively and individually. This is no new thing in the profession. Indeed for as far back as I can remember, engineers have questioned whether the profession occupied the place that it should have in organized society, and to a degree whether it was discharging its obligations to society. The creation of the American Engineering Council gives organic expression to this concern on the part of the profession.

It is natural that in recent years we should have seen an intensification of interest in the social status of the profession. All sorts of things today are being appraised in the light of their social implications, and engineering as a vital process scarcely could be expected, if engineers wished it, to remain aloof from the current trends.

In the profession, as in the general activities of society, we will be helped in our appraisals if we are somewhat careful in our definition of terms. The words "social" and "socialization" carry good implications. They are nice words just as are "individualism" and "initiative." It is rather important that accepting these words in the first instance in their direct and good denotation we do not automatically transfer to their somewhat different connotations the same excellences. This is no matter of word splitting but an essential part of clear-headed thinking.

In recent years we have heard more and more talk about the socialization of this, that, and the other thing. If by socialization we mean the rendering of an institution or of a process truly social in its effects and in its objectives, that is one thing. If by socialization we mean a particular and specific process of attaining professed objectives, that well may be quite another thing.

No intelligent man of good will can for a moment object to a philosophy that holds the justifiable purposes of life to be unselfish, to spread out to the general social body rather than defensibly centering in the individual. This is socialization in its truest sense. The concentrating of more and more power in institutions, the organization of conduct by rules and processes and formulas is not necessarily social. Indeed it may be quite antisocial.

The highest individualism is necessarily fully social. Collectivism may easily be unsocial or antisocial.

A little while ago we heard from Soviet Russia much of the socialization of the family. Had that meant that no family unit any more than an individual has a right to be egocentric, there could have been no quarrel with it. The communization of families was quite a different thing.

In the United States we are today hearing much about the socialization of medicine. If by that we mean the development of more truly social objectives and a more practical realization of them, we are talking of a philosophy which all good men must endorse. In practice, what is called socialized medicine may become collectivized medicine and may run definitely counter to its professed objectives.

So, with the socialization of industry, we may hope for a closer and closer approach to the professional viewpoint that all industry exists for and must be directed to the benefit of the maximum number of the members of the society. This does not necessarily mean the abolition or the restriction of individual ownership, management, or direction, which may result in a collectivization with less in the true sense of socialization.

I think we have a sufficiency of illustrations at hand that the collectivization of the education, the culture, the economy of a country well may concentrate so much power in an irresponsible body politic that the ends of an antisocial government more easily may be achieved, possibly even to the destruction of our civilization.

Now let us take a look at our profession from the viewpoint of socialization. Certainly as one views our heritage in the work of the fathers, we may claim that our origins at least have been magnificently social. The work of Maxwell and of Hertz and of Faraday represented a search for the truth quite unaffected by any slightest element of self-interest—the truth for its own sake and to be shared generously with all mankind. Even in the joy of discovery—in the satisfactions of their scientific pursuits—these men did not seek selfishly to clutch to their own bosoms that which they had created. They sought rather to give it to the world, and no one will deny that the generations past and to come magnificently have been enriched by their sense of social obligation.

Later came other researchers, designers, and inventors. These too sought to create for the service of the race comforts and utilities that would ameliorate living. They handed on their work to you and to me to give extension and realization to what they initiated. Truly this was a socialized practice as well as a social philosophy.

Coming down to current experience, I ask you to examine your own hearts and minds and the conduct of your brother-engineers as to the objectives which you recognize in yourselves—which you find in your fellows.

Address presented at the general session of the AIEE North Eastern District meeting, Springfield, Mass., May 4, 1939.

Is it the attainment of position or acclaim or monetary reward which most actuates engineers, or is it the satisfaction of creation and the realization that that creation serves those who may know little and care less about our processes but who, nonetheless, are the beneficiaries of what we do? On this self-searching, I think we must find that we are practicing an already socialized profession.

At times the more sensitive among us deplore that engineers are not engaged in an individual-service profession wherein a genuinely professional and social objective may as obviously express itself as in such a profession as medicine.

I suppose that in our electrical branch of the profession the preponderance of our membership finds itself working under corporate organization and that easily we can come to think of ourselves as working for those corporations rather than for society, while just as easily we can emotionalize or idealize the work of the doctor and think of him as working entirely for his patients and not at all for himself.

We must admit that it is easier for the individual outside the great business organizations consciously to direct his influence toward social objectives—that with reference to his own work he can make his own philosophy of service a more potent factor in determining its complexion. On the other hand, it is equally to be recognized that a man whose principal living comes from a salaried job is free from the pressure to make each individual act, each particular transaction, serve his own selfish necessities. I wonder whether a representative number of engineers picked at random in one of our great manufacturing or other corporate enterprises would not be found on the average to be as detached and as professional in their approach to their work as an equal number of men similarly selected from any one of the personal-service professions?

Indeed this matter of corporate employment automatically creates a tendency toward socialized operation.

May I for a minute come back to the consideration of mere words as perhaps being indicative of a philosophy. Not so many years ago we commonly spoke of a certain type of enterprise as a public-service corporation. This phrase in and of itself denotes social consciousness. Indeed it denotes a realization of social obligation to serve. More recently the older name has given place to that of public utility which again is just another way of saying "usefulness to the public."

I do not believe for a moment that engineers in the type of employment in which I have been engaged are uniquely set apart from other engineers in corporate enterprise in the matter of rendering a genuine social service through the work of the firms with which they are connected. I make no attempt to claim that the American business system founded on the profit motive and with a great deal of emphasis on private initiative ever has been or is today entirely or even primarily altruistic; but I do insist that in effect the business corporations which engage the services of engineers have been dominated by a realization that a maximum of profit for the owners could result only from a broad dissemination of the products, and that this in effect has led to a high type of realistic socialization of the work of the engineers.

The arts of communication, including radio broadcasting, our great systems of transportation, the well-nigh universal automobile all are cases in point. It is true that the distribution of these devices has not become quite universal. It well may be that the rewards of industry in their production are not ideally distributed. It is a fact that some individuals have made vast fortunes out of their development. The fact not so commonly recognized is that the private wealth so accumulated has not been taken out of the general run of society except in the sense that society has passed back to those who had a hand in these developments a portion of what the developments gave to society.

We miss at times the fact that society did get along before it had the incandescent lamp; that we would have been as well off without the development of the radio systems as we were before they came into existence; that people did live for a great many centuries before the countryside was sprinkled with automobiles. The inventors, the designers, the promoters of these devices working in corporate enterprise created things which the society generally felt to be worth while, and the very fact of their wide distribution under a system of free economy is a pretty clear indicant that a highly socialized service was rendered in adding them to the convenience and comfort of living.

So too it seems to me that the products of engineering skill which flow through corporate enterprise to the less immediate service of human desires and human needs are as truly a socialized service. Because of the very process of distribution, with all of its imperfections, I cannot feel that we have other than a highly socialized profession susceptible of vast improvement through the processes of evolutionary selection guided by a more and more acute social consciousness on the part of the practitioners.

This social consciousness I believe cannot come about through the resolutions of organizations or the statutes of legislators, but will develop with us as it already has developed among us and in the other professions, through the extension to the body of the profession of the spirit which was in the founders. This is a matter of individual growth without which all the mechanism of socialization can accomplish nothing except to set up a machinery. Perhaps the greatest evil of collective operations is in the very fact that they do represent a mechanism for effectuating the purposes of the average, and that by the very process of mechanization the average is lowered by restraint of the best elements in the group.

My own great hope for our profession lies in the fact that there is so much questioning today of the social character of the performance of the engineer. In the very raising of such question we are forced to direct our minds to the things that we as individuals can do more nearly to emulate the notable examples of social direction which already exist in our history and currently among us. Doing that, whatever the nature of our engagement by the society, we are bound to make our individual efforts serve the purposes of our fellowmen.

Lighting for Traffic Safety

L. A. S. WOOD
MEMBER AIEE

Developments in modern traffic lighting provide the electric light and power industry with an opportunity to promote the safety of life and property

THE CRITERION of good street lighting originally was based on the candlepower of the light sources; later the illumination produced determined the acceptability of a system. Now, however, the illuminating engineer is concerned with road-surface brightness and its effect on the visibility of objects themselves. This conception of public lighting has grown out of the application of the "science of seeing" to the solution of the night traffic accident problem and, because it combines lighting and seeing with safety, has come to be known as "traffic safety lighting."

Traffic safety lighting differs from conventional street lighting in respect to the methods of discernment. Conventional street lighting is designed to reproduce *illumination* conditions approaching daylight illumination. On business streets—"white ways"—where commercial interests contribute to the cost of the service, it provides adequate visibility for safety. On thoroughfares and other urban streets where smaller lamps and wider spacings are common, conventional street lighting is inadequate to meet the requirements of modern traffic conditions.

Traffic safety lighting, however, is designed to reproduce *visibility* conditions approaching daylight visibility. These conditions can be provided at reasonable cost by rendering the road surface bright so that objects are seen as outlines (silhouettes), contrasting with the brighter pavement.

Pavement Brightness

The major purpose in the design of traffic safety lighting is to enhance silhouette vision by increasing pavement brightness, and because the burden of avoiding an accident rests mainly upon the automobile driver, it is important that the maximum surface brightness be visible from the driver's seat.

This is accomplished by pendant luminaires with redirecting devices designed to deliver the incident light on the pavement at angles which will locate pavement reflections within the normal vision of the automobile driver. Conventional luminaires of the older type deliver the light to the road surface at acute angles and most of the reflections are skyward, rendering the road surface dark when viewed from the driver's seat, as shown in figures 2 and 3.

On light, diffuse pavement, such as dry concrete, there is a definite relation between brightness distribution on the pavement and the distribution of pavement illumination; but when the pavement has some element of specularity, or the surface is wet, the distribution of pavement brightness bears little relation to that of pavement illumination. "Isolux" curves, such as have been used in the past, do not under these conditions present a correct picture of brightness, for pavement brightness varies not only with the distribution of illumination and the reflection factor of the surface, but also with the angle of incidence of the light and the angle from which the surface is viewed (angle of reflection). Uniformity of illumination is not essential to uniformity of surface brightness, which may exist where there is much variation in distribution of illumination.

Seeing, Stopping Distance, and Speed

According to Doctor Luckiesh (*Proceedings* of Institute of Traffic Engineers, 1938, page 57) there are four fundamental factors associated with the visibility of an object:

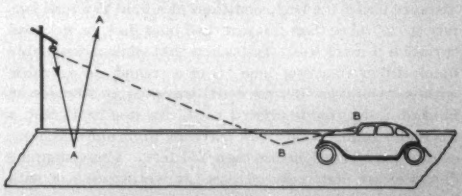


Figure 1. This diagram illustrates the difference between conventional street lighting and traffic safety lighting. Many old types of luminaires in present use direct light as shown by beam A, so that it is reflected skyward and for practical purposes lost. Beam B shows how the light from the luminaire in a modern installation is reflected toward the approaching motorist

size, contrast, brightness, and time. In the lighting of public roads, contrast and time are the important factors in a driver's seeing when his car is approaching a hazard. Together they may be conveniently classified as "visibility distance," the extent of which determines the time (distance) available for stopping the car before a collision results.

On the open road, and on thoroughfares and other urban streets outside business districts, where lighting conditions are inadequate, the driver is dependent on the visibility from automobile headlamps. But headlamp visibility

Based on a paper presented to the AIEE Alabama Section, Florence, Ala., November 18, 1938.

L. A. S. Wood is chief lighting engineer, Westinghouse Electric and Manufacturing Company, Cleveland, Ohio.

Figure 2 (left). Before relighting, this section of West Newton Street, Greensburg, Pa., was an excellent example of "distributed darkness," in which danger lurked. Reflections of the light from the conventional luminaires were largely skyward, and the road surface appeared black to the motorist

Figure 3 (right). After installation of modern luminaires, the same section of West Newton Street, Greensburg, Pa., presents a "silhouette of safety." Reflections from the road surface are in the direction of the driver, to whom the surface appears bright

distance under the best conditions of a light dry road surface is not more than 200 feet, and on a dark or wet road surface it is much less. Tests show that while a reasonably quick driver (reaction time $^3/_4$ of a second) in a vehicle with good braking (64 per cent) traveling at 20 miles an hour on a dry, hard-surfaced road, can stop in 43 feet, a car under similar conditions, traveling at 60 miles an hour, cannot be stopped in less than 251 feet. These stopping distances are materially increased in wet weather or with brakes in less-than-average condition.

Speed in its relation to stopping distance is a function of the automobile driver and should be governed by the condition of the road surface, the quality of the brakes, or speed regulations. Social experience, however, has proved conclusively the impracticability of controlling speed within the range of automobile headlamp visibility distance (20 miles an hour), and because of legislative limitations on beam candlepower, it is impossible at this time to increase headlamp visibility distance to modern driving speeds. The solution of the night traffic accident problem resolves itself, therefore, into increasing driver visibility distance to modern driving speeds by traffic safety lighting.

Visibility distance is just as important in daytime as at night. In daytime it depends on the configuration of the road and can be increased by the elimination of curves, hills, trees, and other obstructions that limit vision. At night the roadway is shrouded in a veil of darkness which can be mitigated only by artificial illumination commensurate with modern driving speeds.

The American Road Builders Association estimates that a visibility distance of 1,800 feet is necessary for safe driving at modern speeds in the daytime. Traffic safety lighting provides a similar visibility distance at night on straight roads.

Where Accidents Occur

The quality of street-lighting service throughout an entire city is often appraised by the effectiveness of illumination on brilliantly lighted business streets, and the inadequate street-lighting conditions prevalent in other parts of the city are overlooked.

Yet it is on thoroughfares and streets outside of the "white way" areas that most accidents occur. A survey of 47 American cities with a total population of 19,000,000, conducted under the auspices of the National Bureau of Casualty and Surety Underwriters, shows that main traffic thoroughfares are the most dangerous city streets. Representing barely 10 per cent of total street mileage, they accounted for 77 per cent of all accidents and 41 per cent of the fatal accidents, 69 per cent of which occurred at night.

Most of the so-called lighting on these streets was designed in the "horse and buggy" days. It was satisfactory for the traffic conditions of that era, but is inadequate to meet the requirements of modern road transportation with its rapidly increasing density and high speeds.

Lacking the commercial appeal of business districts and

financed out of limited municipal street-lighting budgets, the lighting on streets and thoroughfares outside "white way" areas has been sadly neglected. Safety engineers, however, are beginning to realize that traffic safety programs are partially nullified at night without provision for adequate visibility. Traffic safety lighting is now accepted as an essential feature in safety engineering.

New Luminaires

In the production of pavement brightness for the benefit of the automobile driver, luminaire design, lamp placement, spacing, and mounting height are interwoven and mutually dependent. This has led to the development of a new type of luminaire, to be used at a ratio of spacing to mounting height determined by its light-distribution characteristics.

The modern luminaire consists of an inverted parabolic reflector to which is attached a "deformed" pear-shaped globe. The light source, located within the reflector, is completely shielded from the eye of the observer, thus greatly reducing glare. This luminaire produces a symmetrical beam pattern on the pavement surface, and its distribution characteristics are such that it should be used at a maximum spacing of three times the mounting height.

For wider spacing, asymmetric distribution is provided by the addition of supplementary reflectors within the globe on the side opposite the traveled roadway. These supplementary reflectors shield residences from undesirable light emission and spread the beam pattern up and down the street. Thus equipped, the luminaire may be used at a spacing of five times the mounting height.

For still wider spacing, lateral distribution is obtained by the substitution of a single-piece refractor for the globe. This luminaire is suitable for use at a maximum spacing of eight times the mounting height, and a minimum mounting height of 25 feet is recommended.

In modern street-lighting practice, the luminaire is designed for specific applications to be spaced and mounted according to its light distribution. Therefore, the design of modern street-lighting systems is relatively simple. First determine the type of street to be illuminated. Ascertain whether it is a business street, a major or minor traffic thoroughfare, a residence street, or a highway. Then select the luminaire recommended for the particular application and use it at the ratio of spacing to mounting height for which it is designed.

For business streets, the symmetric-reflector type of luminaire is recommended, at a spacing of three times the mounting height. If wider spacings are desired, the asymmetric-reflector type at a spacing of five times the mounting height may be used to advantage.

For major traffic thoroughfares, on which there is a minimum of 1,500 vehicles per hour in both directions, and a combination of surface detail and silhouette vision is desirable, the asymmetric-reflector type is recommended at a spacing of five times the mounting height. In this application, 20 feet is the recommended minimum mounting height. Higher mounting is preferable.

For minor traffic thoroughfares on which there is a minimum of 800 to 1,000 vehicles per hour in both directions, the refractor type is recommended at a minimum mounting height of 25 feet and a spacing of six times the mounting height.

For residence streets where for reasons of economy wider spacings are desirable, the refractor type at a minimum mounting height of 25 feet is recommended, with a maximum spacing of 200 feet.

Used at the ratios of spacing to mounting height for which they are designed, modern street luminaires will provide uniform surface brightness against which objects are clearly seen as silhouettes.

Traffic Safety Lighting Saves Lives

Of all important municipal operating expenditures, street lighting has advanced less since 1911 than any other. During the period 1911 to 1931, street-lighting costs rose only 60 per cent, while traffic increased 5,000 per cent. In the past three years, however, many cities have adopted traffic safety lighting and have found that when adequate night visibility is provided, the night and day fatality experience on streets equipped with traffic safety lighting is practically the same, although before fatal accidents were much more numerous at night than in the daytime.

Detroit, Mich., for example, now has in operation approximately 300 miles of traffic safety lighting on many of its main thoroughfares. According to L. J. Schrenk, general superintendent of Detroit's lighting commission, the ratio of night to day fatalities on these roads has been reduced from 7 to 1 before relighting, to 1.57 to 1 under adequate night visibility conditions.

Further analysis of Detroit's accident records shows that traffic safety lighting decreases many of the traffic fatalities which in the past have been attributed to driver or pedestrian faults.

Summarizing, in the 15 classifications where according to the police records, "the driver was at fault," there were,

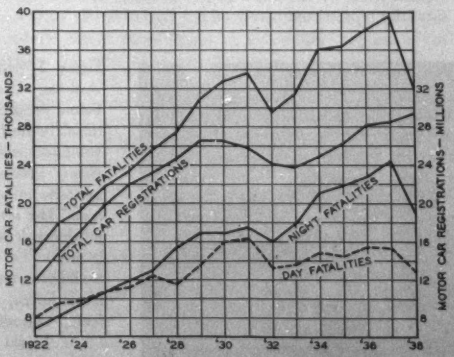


Figure 4. Comparison of motor-vehicle fatalities with total car registrations during the period 1922–38

in the three years prior to relighting, 54 night and 6 day fatalities. After traffic safety lighting had been installed on these streets, only 7 night and 2 day fatalities occurred in 18 months.

On ten miles of Hartford, Conn., streets where lighting was improved from 0.18 to 0.43 lumens per square foot, complete records of all accidents involving death, injury, or property damage over $25.00 show a decrease of 46 per cent in night accidents after relighting. On similar streets not relighted, night accidents increasd 4.1 per cent in the same period.

A survey in Evanston, Ill., under the direction of the traffic engineer of the National Safety Council, showed that after the installationof a complete new lighting system, night accidents resulting in personal injury or death were reduced 23 per cent. During the same period day accidents rose 30 per cent, because of increased traffic.

James E. Davis, chief of police of Los Angeles, Calif., states that inadequate lighting is the greatest single factor contributing to traffic hazards in city streets. He points to Los Angeles' fatality record for February as striking proof of this statement and predicts that provision of adequate safety lighting, which is being installed as fast as equipment is available, will save 78 lives a year and reduce by more than 15 per cent the Los Angeles automobile death rate.

National Fatality Records

In 1938 the United States experienced its second annual decrease in motor-vehicle fatalities since the turn of the century and its lowest traffic death total since the depression years of 1932 and 1933 (see figure 4). The improvement was due to intensive national safety activity in which many communities competed. Although more than 7,000 lives were saved in 1938 as compared with the peak death figures of 1937, the death total of 32,000 remains far too high. Moreover lacking provision for night visibility, the intensive safety campaigns are more effective in the daytime. Of all fatalities, 59.4 per cent (only 1.7 per cent less than in 1937) occurred at night. Twenty years ago, night fatalities represented barely 30 per cent of total.

Successful Programs Adopted

Many power companies already have adopted progressive public lighting programs, with success which demonstrates the feasibility of such activity. A notable and convincing example is the modernization program adopted by the West Penn Power Company. This program was introduced in 27 communities in 1938. Approximately 1,500 new luminaires were installed during the year and 24 contracts were renewed in advance of expiration, in addition to three that expired during the year.

The first city on the program was Greensburg, Pa., a community of 16,000 located where many national highways converge. A complete report covering every street and byway in the city, with recommendations for traffic safety lighting, was prepared along with promotion folders emphasizing the value of adequate visibility. The recommendations may be summarized:

	Present System	Proposed System	Proposed Increase
Total candlepower	231,250	384,250	153,000
Net annual cost	$20,079.50	$32,263.85	$12,184.29

This "progressive planned street-lighting program" covering a five-year plan was adopted in its entirety by the city council on November 4, 1937. On November 22, the council decided to put the entire program into effect immediately instead of spreading the improvements over a five-year period.

The plan was completed in five months and dedicated in the fall of 1938. The new system, which has proved to be all that was expected, increases the annual cost of street lighting in Greensburg from $1.30 to $1.95 per capita and the citizens are delighted at the night visibility conditions purchased by the annual outlay under their five-year contract (see figures 5 and 6).

The promotion of traffic safety lighting is a humanitarian program. The electric light and power industry is in a key position to assume leadership in night traffic safety and to perform a valuable public service toward the reduction of night accidents.

Figure 5 (left) shows Penn Avenue, Greensburg, Pa., before relighting. Conventional luminaires were used, equipped wtih 6,000-lumen lamps; spacing was 100 feet opposite, mounting height 18 feet. The same corner, after relighting, is shown in figure 6 (right). The new luminaires are reflector type, with 5,000-lumen lamps; spacing is 100 feet opposite, mounting height 22 feet

The Engineer as Conservator

C. W. KELLOGG
MEMBER AIEE

Engineers, as conservators of capital, have a special duty to sound the alarm against the dangers underlying a continuation of wasteful governmental spending, says this prominent engineer.

"ETERNAL vigilance is the price of liberty." From this proposition, which has attained practically the standing of an axiom, follow several corollaries: First, eternal vigilance is the price of all worth-while things. Anything that does not require constant care and attention or effort to conserve naturally is considered of little value because we come to take it for granted. As the proverb says: "Blessings brighten as they take their flight." A second corollary is that at times we should pause to consider the bases of our general situation in order to see what freedom, or other fundamental factor of our lives or businesses, is in danger of being lost through lack of appreciation of its value and importance, so that we may take thought on how to conserve it. In the third place, in our democratic country the people themselves must look out for their own fundamental interests, for nobody else will do it for them.

On the basis of the broad principles just outlined, I should like to discuss briefly a basic problem of our country which I believe should appeal especially to engineers. I refer to the present fiscal policy of our National Government.

The problem is clearly portrayed by a wealth of public statistics. It may be summarized as follows: We are now nearing the end of the ninth consecutive fiscal year in which our National Government has spent more than it took in and the tenth year, which begins July 1, 1939, will show a continued heavy deficit. During the nine-year period now ending the *increase* in national debt resulting from deficits is nearly 25 billion dollars and the total national debt by June 30, 1940, will probably approximate 44 billion dollars. The major part of this debt has been forced upon the banks of the country at abnormally low rates of interest, such low rates being produced largely by the very excess of unneeded credit which the loans themselves create. This has reacted on the return on capital in all lines, thus forcing the permanent investors, like the life insurance companies, savings banks, and educational institutions, to see the return upon which their beneficiaries depend almost cut in two. To date, at least, we have hardly begun any effective moves to stop the destructive process of borrowing money to pay current expenses. I believe, however, that serious thought on this vital matter is gradually gaining momentum.

The immediate threat of this ruinous fiscal policy is definitely to the thrifty class, although all will inevitably be caught by it in the end. The special interest of the engineer in this whole matter is that the very nature of his professional work has been to conserve capital, to see that it is expended on physical property in the most economical and effective manner. Without the skill and experience of the engineer, serious waste of capital would continually recur; and the great economic value of the engineer to the community (in the conservation of capital by the avoidance of waste in its use) is vastly greater in amount than the cost of his services in its conservation.

Capital and the Engineer's Job

Not only does the engineer thus save capital for the community, but his own welfare and activity depend upon the constant production of new capital to be applied to useful development. A policy that cuts down the return on capital inevitably discourages the accumulation of capital, for the only incentive to the thrifty man to save, and to conserve what he saves, is the hope of a reward for his self-denial and forethought in the shape of a fair return. Wiping out or cutting down the wages of capital, therefore, directly affects the engineer's job.

The fact that the Federal deficits of recent years have been built up in the face of taxation as heavy as at any time in our national history is a strong indication that the deficits are principally due to wasteful spending. When taxation is already so heavy as to be a serious deterrent to business expansion, it is manifestly inexcusable that even these excessive tax levies should be hardly more than half enough to pay for the yearly outlay. Such folly leads to financial chaos with a nation just as surely as with an individual; the only difference is that in the former case it takes longer to accomplish, because of the huge resources that can be drawn on, especially in a naturally rich country like the United States. The engineer knows from his regular experience that he must "cut his cloth" to suit his client's purse and that a given proposed development, no matter how otherwise desirable, cannot be carried out unless adequate funds can be made available.

It seems to me that in the ignoring of this point has been the essence of our national financial folly. Hardly an individual can go through life without encountering occasional periods of financial stress, when, because of illness or financial reverses or some special requirement,

Address presented at the general session of the AIEE North Eastern District meeting, Springfield, Mass., May 4, 1939.

C. W. KELLOGG recently was elected the first full-time president of the Edison Electric Institute, New York, N. Y.; he was formerly chairman of the board, Engineers Public Service Company, New York, N. Y. A biographical sketch appears in the "Personal Items" section of this issue.

expenditures for a time must exceed income. Such a period calls for temporary loans, or the sale of assets, or other special arrangements; furthermore, it calls for the most careful scrutiny of all expenditures, so as to make sure that precious assets are not needlessly wasted. For a prudent individual, such a time of stress would hardly be made the occasion for building an unneeded wing to his house or for branching out needlessly into any new lines of family activity.

Our national economy is but the integral, of which each individual economy is the differential. There is no doubt that the collapse of values and of business activity which followed the debacle of 1929 represented for the nation just the sort of emergency period that most individuals encounter occasionally in an ordinary lifetime. Did our Government meet this situation with the effort (which I think we can agree a prudent individual should exert in similar circumstances) to confine those expenditures made on borrowed money to the absolute necessities of the case? In frankness, I think we must admit that it did not.

Goverment Spending in Individual Terms

Emerson's perhaps most-quoted remark is that one to the effect that every human institution, no matter how great, is but the lengthened shadow of a man. By the same reasoning the most enlightening way to appraise any great institution is to reduce it to one-man proportions.

Suppose you had a neighbor whose average annual income over a nine-year period had been $4,028 and whose average annual expense $3,113, so that he averaged to save during those nine years $915 annually, or an aggregate for the period of $8,235. Based on this admirable showing you would be justified in the opinion that this neighbor had handled his financial affairs in a sound and satisfactory manner and you would be right in assigning to him a high credit rating for his size.

Suppose further that toward the end of this nine-year period your neighbor found his income falling off and yet had substantially greater burdens to bear than before. In the lowest year of the next nine-year period his income was but $2,006. By strenuous effort he succeeded in building back his annual income so that for the second nine years it averaged $3,929; in fact, for the next to the last year of this second period he had worked it up to $6,242. Yet in this second nine-year period he spent an average of $6,411 per annum (more than twice what he had averaged in the previous period), not counting a large nonrecurrent item of $2,000; and in the last year of the second period he spent $9,492. So that although during the first nine-year period he saved $8,235, in the second period he went behind on current account, to the extent of $22,338.

Having in mind the excellent showing he had made in the early period with an average annual income of $4,028, I think you would be justified in wondering why, when his income in the best year of the second period was more than 50 per cent above his former average, he went in the hole even that year $1,384, where before, with the lower average income, he had saved $915. You would be less than human if you did not seriously doubt if he had made anything like the same effort to save in the later period that he had made in the earlier period. I believe your doubt would be so great that you would feel it necessary to revise completely your earlier verdict as to the credit standing to which he was entitled.

If in this suppositious case you call the neighbor "Uncle Sam" and multiply all figures by a million, you will get an approximately accurate picture of our current Federal finances for the two nine-year periods ending, respectively, in the middle of 1930 and of 1939.

If you should think that I have been too general in my claim as to the wastefulness of expenditures during the nine years just ending, let me enumerate a few main items:

1. Increase in expenditure for public works in the last nine years compared with the previous nine years	$ 6,075,000,000
2. Payment of soldiers' bonus nine years before the due date of the certificates covering it	2,000,000,000
3. Relief expenditure waste (since 1933) consisting of the difference between $23 per person per month spent in state and local relief and $65 per month per man spent by WPA. This ratio, applied to the $14,178,000,000 actually spent, shows an excess of	9,161,000,000
4. Simple interest on the foregoing at 2 1/2 per cent per annum	1,346,000,000
These four items are rough "measuring sticks," but they amount to the huge total of	$18,582,000,000

Thus, about three-quarters of the increase in Federal debt during the last nine years can be ascribed to unnecessary extravagance.

Credit Needed for National Defense

Another important element in the plans of a thrifty individual is to save for a rainy day, to avoid a load of debt today in order to conserve borrowing capacity for future periods of particular stress. The "rainy day" that now appears to be fast approaching in the United States is necessary preparation on a big scale for national defense. Could anything show more clearly how we have wasted our resources on unnecessary extravagance than to find ourselves loaded with the present debt of over $40,000,000,000 at a time when we may well need most of that borrowing capacity to carry us through a real pressing requirement of our national safety?

It is amazing, in view of the wealth of historical evidence on the subject, some of very recent origin, to find men high in our Government seriously advocating, as a relatively fixed and permanent policy, the present method of so-called "deficit spending." It can mean only one of two things: either that we are deliberately loading onto our children and grandchildren current costs for which they will get no benefit; or that we propose to see the obligations of the United States Government repudiated on account of future inability to discharge them due

to present profligacy in wasting our resources. Either horn of this dilemma we should recoil from aghast; and yet, if present spending trends continue, one or the other is unavoidable. Meanwhile, even if we are willing to turn our backs in a cowardly manner upon these two eventualities, the fact remains that already the policy has virtually cut in two the return on capital in this country.

Conditions Causing Cheap Money

Perhaps it might seem at first thought that cheap money is a good thing for the country and that cheap capital should reduce the cost of goods or services to th extent that these costs depend on the use of capit What such superficial reasoning overlooks is that whe money is cheap it is so because there is relatively litt demand for it and that this relatively small demand aris from fear of the effects of the fiscal policies of the Government. The times of easy money in the United States have never been prosperous times (usually for the reason just stated); conversely, the periods of great prosperity have always been those when capital earned a fair and ample rate of return, such as encouraged the thrifty to save it and the enterprising to employ it. Engineering is the handmaiden of prosperity; it is most useful when most used and that means when the maximum amount of new capital is being laid out and needs expert care to lay it out to the best advantage.

Even the artificially created cheap money of the present era is more apparent than real, for it applies only to borrowed money. The real working money of the enterpriser, which is the basis of all true economic progress, is not cheap, partly because of the fear of the future just mentioned, and partly because, with the present-day heavy taxes, the balance for return on such enterprise money is only too likely to be a red figure.

This whole fiscal policy has been like killing the goose that laid the golden eggs. This particular goose is the average thrifty citizen. With inheritance and surtaxes, the man of great wealth has become a relatively minor source of new investment capital. In aggregate size he never was as large as his individual conspicuousness would seem to indicate. No, the backbone of capital creation in the United States is the aggregate savings of millions of frugal citizens of relatively small individual wealth; and it is this person that is being battered down so that he no longer can contribute as he used to in helping others, because he can barely take care of himself.

The question, therefore, that comes directly to engineers, the natural conservators of the capital of the people, is, what ought we to do about the matter? We owe it to ourselves and to our country to do all in our power to spread the information among the people. One difficulty in discussing Federal finances with the average man is that the figures are so large as to seem to be beyond his grasp. This can be overcome by the unit method I have used. Another hurdle is that Federal finances seem so far away that the direct effect on each individual is not easy for him to visualize. Every man who is supporting and raising a family of children has a lively interest in the burden of debt now being built up for them to carry. Every young man and woman starting out in the world is right now at grips with the load which Government debt imposes; either they must work to pay it off, or they must see the value of their money destroyed if the debts cannot be paid and have to be repudiated. Literally no one can escape a personal effect from continued Government spending in excess of a level of tax earnings that is already up to about the limit that industry can carry.

We can all support actively the publicity on this subject being undertaken by various national and local organizations. The National Economy League, New York, N. Y., has recently published a most timely pamphlet entitled "How to Balance the Federal Budget." The necessity for national economy and retrenchment is already being valiantly pointed out by some leaders in Congress. This body, because of the many varied local interests necessarily represented, is not ideally suited to economy; but every Congressman really desires to represent faithfully the wishes of the people upon whose votes he depends. The members of both houses of Congress should be told how deadly in earnest the people are about their public finances. They cannot know unless they are told. They doubtless hear plenty from those who expect to receive part of the extravagant expenditures; they should hear also from those who have to suffer from those expenditures; they must be made to realize, before it is too late, that if the public debt continues to pile up as it is doing, everyone, both receivers of, and contributors to, public funds, will be engulfed in a common calamity.

Engineers Should Publicize Economy Need

The general purpose of all engineering societies, to which of course the AIEE is no exception, is to further the improvement of the art by the study and discussion of better and more economical ways of accomplishing results of a purely engineering nature. This is natural, due to the essential function of the engineer as the conservator of the people's capital. It is futile, however, to talk of such improvements when the very capital for whose conservation they are intended is being dissipated or destroyed by governmental fiscal policy. It seems to me now, therefore, more important than anything else to stress this imminent underlying danger.

Let us not be discouraged in our efforts by the vast scope of public opinion. We must remember that in any democracy the general opinion is the sum of millions of parts. The tide is already setting in toward an appreciation of the necessity for Government economy. Each of us has friends, neighbors, business associates, through whom the discussion can be widened. Each of us has Congressmen to whom he can write. Each of us, representing that part of the community most expert in the conservation of capital, has, for that reason, the special duty to sound the alarm. May no engineer be found recreant to that duty!

Utilizing Heat From the Sun

C. G. ABBOT

Modern development of aluminum products and vacuum devices makes feasible and economically practical the wholesale production of solar-heat appliances for various purposes, according to an authority on solar radiation who has been experimenting with such appliances for 20 years.

IN LARGE regions lying in the low latitudes desert conditions prevail. Day after day the sun glares down, occasionally dimmed a little by cirrus clouds, or perhaps by a few heaping cumuli. In such regions 80 per cent or even more of the hours of daylight would be useful for furnishing solar heating.

Quantity of Solar Energy

The quantity of energy available from solar radiation under such conditions is immense. As I shall show in what follows, we may count on the possibility of converting 15 per cent of the energy of such solar rays as are intercepted by our devices into mechanical work. Assuming that, to avoid appreciable losses through shading one unit by another and to allow plenty of room for other purposes, only one tenth of the area available is actually covered by heat collectors, and further allowing for night and cloudy weather, still the State of New Mexico could supply from solar radiation over ten trillion horsepower-hours per year of mechanical power. That somewhat exceeds the power possibilities of all coal, oil, and water at present used annually for heat, light, and power combined in the United States.

Intermittance and Storage of Solar Power

Like hydroelectric power, solar power demands no continuing expense except for care and interest on the investment. Unfortunately, however, solar power is subject to the drawback that it ceases during night hours, and when the beam is intercepted by clouds. There are certain uses, such as pumping water for irrigation, for instance, where this intermittance is no serious objection. But for most purposes power must be available at all times. Hence to become a great industrial factor solar power demands the association of storage of energy, either as heat, or in chemical, electrical, or mechanical forms. As efficient production of solar power must nevertheless be the first step, I shall postpone considerations of storage for the present.

Water Distilling and Cooking by Solar Heating

There are other uses for solar heating which do not so seriously involve storage. Among them are the distillation of water and the cooking of food. It is stated that in Bermuda the past year was so deficient in rainfall that fresh water was imported from New York, although the Atlantic Ocean is all around. In parts of some western states the water is too alkaline for drinking or for storage batteries. In Florida the water stinks with hydrogen sulphide in some localities. Under such conditions as these the solar distilling device should be useful. For cooking, though it is not practical in cloudy regions, it is easy to provide heat storage for 24 hours, and with a solar cooking device the ovens may be kept at baking temperatures for weeks and months continuously in the more cloudless parts of our country.

Recent Commercial Products a Boon to Solar Devices

The cheap production of efficient solar-heat devices has awaited the commercial development of aluminum products, now so plentifully used in the industries, and the common use of vacuum devices, which came with the incandescent lamp and radio industries. Formerly inventors relied on glass mirrors which were heavy, costly, and not durable. It is now possible to purchase the so-called "Alcoa" in thin sheets, which readily take the curvature of a suitable cradle form without previous shaping. This material reflects over 80 per cent of solar radiation, and may be used for years without dimming. As the loss of heat in the boiler at the focus of a solar-radiation appliance is the great obstacle to be provided against, the possibility of making cheap glass jackets enclosing high vacua like thermos bottles is the other great improvement which has become practicable in recent times.

Mechanism for Following the Sun

The daily march of the sun through the sky, and its yearly march from north to south, must be considered. If one uses a spherical boiler and a circular mirror he must allow for both of these apparent motions, as Eneas did at the ostrich farm, Pasadena, Calif., about 1905. If, however, one uses a tubular boiler parallel to the axis of the earth, the yearly adjustment is unnecessary and the daily motion can be allowed for merely by rotating the parabolic cylindric ray-concentrating mirror about an axis coincident with that of the boiler tube at the rate of 15 degrees per

Address presented at AIEE New York Section meeting, New York, N. Y., February 23, 1939.

C. G. Abbot, secretary of the Smithsonian Institution, Washington, D. C., and director of the Smithsonian Astrophysical Observatory, has been engaged in researches on solar radiation since 1895, when he first became an assistant at the Observatory. He holds the degrees of bachelor of science (1894) and master of science (1895) from Massachusetts Institute of Technology; doctor of science, Melbourne University (1914), Case School of Applied Science (1931); doctor of Laws, Toronto University (1933). Recipient of the Draper Medal of the National Academy of Science and of the Rumford Medal of the American Academy of Arts and Sciences, he is a fellow of the latter society and member of several other scientific societies in the United States and other countries, and author of several books on the sun and stars.

hour. The boiler tube may be firmly fixed, and with the simplicity of the mechanical driving of the mirror, renders this arrangement preferable to all others for most purposes. The mirror may be driven by clockwork, or, if electric facilities are available, still better by a 60-cycle synchronous motor through a worm and wheel.

I have used both types of driving. Our solar cooker on Mount Wilson, having been built long ago, is cumbersome. It has a heavy mirror, 8 feet wide by 12 feet long. I attached to the mirror a grooved wheel 30 inches in diameter coaxial with the lower trunnion of the mirror. A steel wire in the groove of the wheel supported a weight of about 200 pounds, sufficient to rotate the mirror toward the west. Through a second steel wire wound in the groove in the opposite sense, the weight also drove a clockwork. This clockwork train ended in a flyvane. A long hand rotated with the central shaft and once in each revolution was stopped by a displaceable pin. The long hand would make a full rotation in about three minutes. A common alarm clock was provided with a wheel of 12 pins on the back of its hour shaft, and these pins, acting through a lever escapement, displaced the stop-pin once each five minutes. Hence the mirror moved intermittently as governed by the alarm clock, and was never more than one minute from its proper position to focus sun rays upon the heater tube. Still simpler clockwork contrivances may be used to drive smaller mirrors for solar heating devices.

Domestic Water Heaters

Those who have visited Florida or southern California may know of the roof water-heaters which are used considerably for providing hot water for bath and other household purposes. A shallow depression is let into the southern roof exposure, and lined with blackened sheet metal. Therein is supported a blackened grid of pipes like a steam radiator. The boxlike depression is covered tightly with glass windows. Water circulates through the piping, and thence to a reservoir at a higher level within the house. Such a system acts by gravity like the water-heater system of a cook stove. If the reservoir is well insulated from heat losses and the location is relatively cloudless and never freezing, such a system is found to be very useful for furnishing hot water both day and night, without maintenance cost or attention. While on Mount Wilson, several years ago, I bought 200 feet of black garden hose. I coiled 150 feet of it in a flat coil upon a wooden X, and carried it up the ladder to the south side of the cottage roof. The other 50 feet I connected to the water hydrant in the yard and to a spigot in the bathtub. By this simple arrangement we could draw five gallons of very hot water each half-hour on every sunny day.

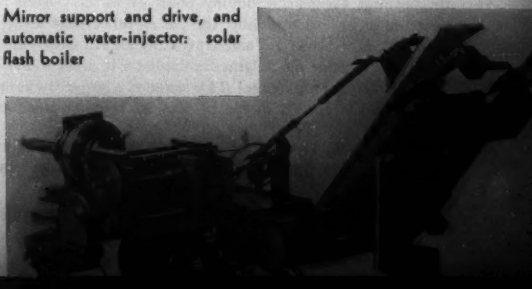
Solar Cookers

When we attempt cooking by sun heating we require temperatures far above the boiling point of water. Hence some other liquid of a much higher boiling point is desirable as a heat conveyor, otherwise high pressures and evaporation would be encountered. In our cooker on Mount Wilson I used engine cylinder oil within a blackened metal tube in the focus of the mirror. About 60 gallons of the oil were employed in the system, so that there was a large capacity for heat, and cooking could be done by night as well as by day. However, it required about two days of sun to get the system heated initially, because near-by trees limited the sunshine to seven hours per day.

In recent installations I have preferred to use "Arochlor," a nearly black liquid product of the Monsanto Chemical Company. I have made this liquid almost completely absorptive of sun rays by adding a small amount of lampblack in suspension therein. While engine cylinder oil chars somewhat and evaporates considerably at 210 degrees centigrade, "Arochlor" does not boil below 350 degrees centigrade, and evaporates scarcely at all at lower temperatures. This liquid, being highly absorptive, may be used directly in the vacuum-jacketed glass focus tube. Circulation may be provided by bringing back from the oven sheath a small metal or glass tube within the focus tube almost to its lower end. Such a focus tube passes freely through the hollow trunnion at the upper end of the mirror, and is sealed by a well-designed stuffing box to the metal sheath which encloses the oven. According to whether one wishes for a quickly heating oven, or for one to remain hot through temporary cloudiness and the night hours, the oven sheath contains little or much of the liquid. This part of the system may be surrounded by a thick layer of glass wool for insulation, leaving, of course, means for reaching the oven door.

In another embodiment of the cooking device, I have sealed the glass vacuum-jacketed focus tube to a vertical cylindrical glass jar which contains the liquid. Within the liquid is an inner glass jar used as the oven. The food to be cooked is brought into the oven from above. In this embodiment the outer of the two glass cylinders may be itself surrounded by evacuated space. This makes a very beautiful, highly efficient, and quickly heated oven of small capacity. For a large installation it is better not to use the liquid directly as the absorbing medium, but to contain it in a blackened copper tube, itself surrounded by a vacuum jacket of glass. This arrangement lends itself to a more robust connection of the heater tube to the oven jacket. Liquid may then be supplied to give a large capacity for heat and to heat a plurality of ovens.

The following figures will indicate approximately the size of an outfit for solar cooking. In clear sky conditions one may depend on from 1.2 to 1.4 calories per square centimeter per minute of energy in the solar beam. Using the lower of these figures we have still to encounter the



Mirror support and drive, and automatic water-injector: solar flash boiler

following efficiencies: mirror reflection 82 per cent; vacuum jacket transmission, if direct to liquid, about 89 per cent; if through a blackened metal tube to liquid, about 80 per cent. Hence there remain about 0.79 to 0.87 calories per square centimeter per minute. The maximum temperature which a mirror will maintain in an oven depends on the rate of loss of heat. The time required to approach that temperature depends on the capacity of the oven and its surroundings for heat. These variables cannot, of course, be predicted without specifications. But it may safely be said that with good design a mirror, with a surface of 4 by 8 feet will keep two ovens of ordinary size hot enough to bake biscuits well, by night as well as by day, in any fairly cloudless regions in the temperate zones.

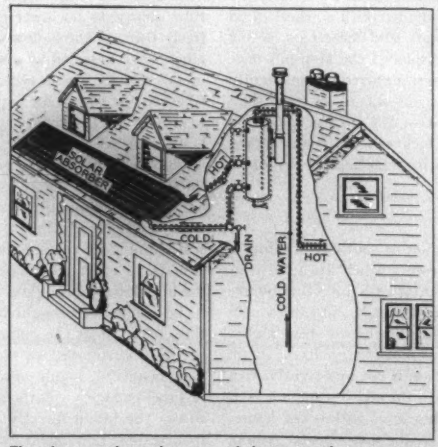
I have constructed a toy cooker with a mirror surface of 15 by 20 inches to warm an oven 3 1/4 inches square, 2 1/2 inches high, and insulated by glass wool 3 inches in thickness. It requires about an hour to heat the oven to about 130 degrees centigrade above surrounding temperatures, and the oven bakes cakes 3 inches square very nicely in a half hour.

Solar Water Distilling

Distillation of water may be very efficiently done with solar heating. The arrangement of the mirror is similar to that just described for cooking purposes. In this case, however, the elongated vacuum jacket, like a thermos tube except that it is not silvered within, is supported in the focus of the mirror with its open end at the bottom, and its closed end extending a foot or more above the top of the mirror, which rotates on rollers bearing the hollow trunnions of the mirror. In the case of the cooker, and also of the power flash boiler, soon to be described, the absorber of rays is made as small in diameter as possible in order to reduce heat losses, so that the temperature may run high. In the solar water distiller, however, the temperature cannot exceed the boiling point of water. With a vacuum jacket surrounding the focus tube, heat losses at that temperature are small per unit area. Hence the focus tube is made much larger in diameter in order to provide freer escape for steam. This requires a larger vacuum jacket than is needed in the devices for cooking and for power.

The water to be distilled is poured into a vessel supported behind the mirror and nearly at the level of the upper end of the mirror. A long snout runs from the bottom of the water vessel down behind and parallel to the mirror, and, bending at right angles, comes up to join the focus tube of copper, which is blackened outside to absorb solar rays. Thus the water flows by gravity from the vessel to an equal height within the focus tube. Within this snout and focus tube is a smaller tube for steam. It extends from above the level of the water in the vessel to above the level of the mirror in the focus tube. It is open to the atmosphere above the vessel, and open to steam above the water in the focus tube. A branch leaves the steam tube at its lowest point, and passes sealed through the wall of the snout, so that distilled water may drop from the steam tube into a receptacle underneath.

Only one difficulty is encountered with this device. The steam must be permitted to escape through an orifice so protected that the surging, boiling water within the focus tube does not ever reach that orifice to mingle with the condensed steam. This is accomplished by a series of umbrella diaphragms along the upper part of the steam tube, and by using a diminished orifice well shielded by a cap.



This diagram shows location of the parts of an automatic water heater using a solar absorber and single storage tank

The efficiency of the device is very high. The steam being condensed by flowing through the entering water, that water reaches the lower end of the boiler tube at almost boiling temperature. Thus it is only the latent heat of steam that must be provided by solar radiation, and not the heat required to raise water to boiling. In experiments made in Florida in March 1938, the stinking water of Arcadia was distilled to perfect purity and odorlessness. Distillation commenced within five minutes after the sun came out of a cloud. A mirror of 11 square feet of surface distilled between two and three gallons of water, entirely automatically in one cloudless day.

The Flash Solar Boiler for Power

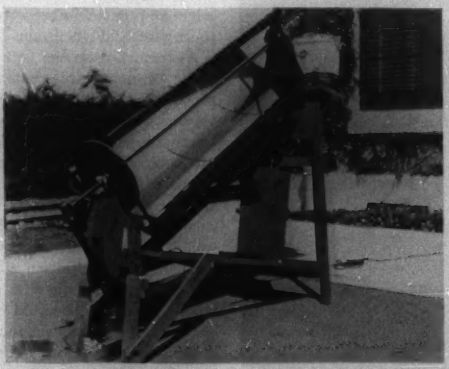
Since cumulus clouds are apt to obscure the sun occasionally in regions suited to solar power production, the flash boiler, rather than the boiler of large heat capacity, is indicated. For if it takes an hour or more to raise the desired steam pressure, many days will be wasted when the sky about the sun is clear one-half of the time. Accordingly my efforts in recent months have been directed toward the development of the automatic flash-boiler

solar engine. That is an engine of a single tube boiler protected from heat losses by an elongated glass vacuum jacket and fed by a current of water automatically graduated in flow by the temperature of the boiler. The device is intended to raise full steam pressure within five minutes after solar exposure. Should the sun enter a cloud the water supply is immediately cut off. Should the steam pressure rise above the desired maximum the water supply is increased. Thus the boiler is fully automatic, and takes advantage of all the clear sky which comes between clouds.

It would be convenient if it were practicable to have the glass vacuum jacket open at both ends so that water could flow in at the bottom and go out as steam at the top. But the unequal linear expansion of the inner and outer tubes of the jacket is difficult to allow for in a permanent sealage. Accordingly I have preferred to make the vacuum jacket surrounding the boiler tube like an elongated thermos bottle with open end up. This requires the water tube entering at the top to pass through the steam to the lower end of the boiler. I introduce two tubes sealed upon the water tube within the boiler, which are called, respectively, the spreader tube and the vacuum-jacket tube. The spreader tube encloses the water tube in the lower two-thirds of the length of the boiler tube, and forces the water to circulate in a thin layer against the inner wall of the boiler tube, so as to be most favorably situated to burst into steam. The vacuum-jacket tube is sealed upon the water tube in the upper one-third of the length of the boiler tube, so as to reduce the tendency of the entering water to cool the superheated steam in the upper part of the boiler tube.

Automatic regulation of the water supply is accomplished as follows: A pump is provided whose stroke is continuously adjustable between the limits zero and the greatest required. The essence of this regulation consists of an eccentric pin forming part of a shaft driven by the same small synchronous motor that rotates the mirror. One end of the pin is coaxial with the shaft bearings, but the other end revolves in a small orbit. The shaft carrying the pin is mounted in a carriage, displaceable longitudinally, so that according to its longitudinal position the pin gives more or less throw to the pitman that works the pump.

To govern the position of the carriage, motion is imparted by a screw driven by a tiny d-c motor operated by dry cells. The operation of this motor forward or backward is governed by a suitable multiple contact switch. The switch is operated by a lever system worked by the differential expansion between the boiler tube and an invar tape attached to the lower end of the boiler tube. Hence the temperature of the boiler, which is the index of the prevailing steam pressure, governs the position of the carriage. Mounted upon this carriage is the uniformly rotating eccentric pin which in turn governs the stroke of the pump that forces water into the boiler.



This device for distilling water by solar heating was used by the author in Florida in 1938

Efficiency of Solar Flash Boiler

Regarding the efficiency of conversion of solar energy into mechanical power by the flash boiler, the following computations are pertinent:

A. Efficiency of the boiler, assumed temperature 190 degrees centigrade:

Mirror reflection	.82 per cent
Transmission by vacuum jacket	.85 per cent
Absorption by boiler tube	.95 per cent
Loss of heat through the jacket	.10 per cent
Boiler efficiency $0.82 \times 0.85 \times 0.95 \times 0.90 =$	.60 per cent

B. Thermodynamic factor for perfect engine:
Assumed temperature of condenser ..... 30 degrees centigrade

Efficiency factor $\frac{190° - 30°}{190° + 273°}$ ..... 34.5 per cent

C. Assumed mechanical efficiency of engine ..... 75 per cent

D. Final Result. Efficiency of conversion of solar to mechanical energy:
Factor $= 0.60 \times 0.345 \times 0.75 =$ ..... 15.5 per cent

In the experiments of most earlier inventors, the protection of the boiler tube by a vacuum jacket was not practicable; the cheap but accurate construction of the mirror to give high reflection with permanency was not feasible; and the simplest arrangement to follow the sun was not generally used. Consequently the cost was up and the efficiency was down. Hence these earlier devices were quite unable to compete with power from coal or water under most conditions. With the high efficiency and great simplicity of the present flash-boiler scheme, I compute that power can be had from the sun at not exceeding 0.5 cent per horsepower-hour, and still give a good return on the investment.

I wish, however, to refer to one of the earlier inventions in which efficiency was sacrificed for cheapness. It was that of Willsie and Boyle, who installed a solar power plant at Needles, Ariz., about 1910. Their scheme comprised a large shallow black-bottom pond wherein the water attained temperatures considerably below the boiling point. This heat they used to drive a

sulphur-dioxide engine, cooled by the evaporation of water. They claimed that their device was able to compete with coal in that locality, although both its boiler efficiency and its thermodynamic efficiency were low. It appears not to have come into much commercial use, however.

Storage of Solar Heat or Power

I will now consider briefly some suggestions relating to the storage of heat or of power from the sun. As everyone knows, heat is prone to dissipate itself. There are no insulators against heat conduction comparable in efficiency to those which prevent the flow of electricity. My friend, Dr. Cottrell, however, has proposed a scheme which may be worth a trial. He suggests a silo-shaped, cement-lined pit in the ground, filled nearly to the top with dry coarse sand, and roofed over. Above the sand lies a layer of perhaps ten feet of glass wool, such as is used for roof insulation. A pipe leading from the solar heater to the center of the upper surface of the sand has an appropriate network of branch pipes covering the surface. A similar network at the bottom of the pile leads to an outlet pipe, and thence back to the heater. An automatic pump, which runs only while the focus tube is hot, draws hot air through the solar heater into the top of the sand. Owing to the notoriously bad conductivity of dry sand, and the high degree of protection from upward convection and conduction offered by the thick layer of glass wool, the sand pile receives the heat, and keeps it in a horizontal layer. The heated layer gradually works down, until, if the storage operation is continued very long, the whole sand pile reaches a temperature nearly as high as the air in the focus tube itself. With a sand silo of sufficient capacity, Dr. Cottrell thinks the efficiency would be so high that when the heat was drawn away, perhaps months later, by reversing the circulation of air, the air would come away from the top of the sand very nearly as hot as it formerly entered. No one has tried this interesting scheme, but it would be interesting to do so. Should it succeed, it might show the way to use the heat of summer to warm one's house in winter.

Electric storage batteries are so well known that it is unnecessary to point out that solar power may be conserved thereby for night use. It is the cost which handicaps this proposal.

Chemical storage might be done by electrolyzing water, and saving the hydrogen to be burned in air with boilers to generate steam. This involves the problem of successful use of hydrogen as a steaming fuel.

Mechanical storage could be accomplished by pumping water to a high-level reservoir, to be used in a hydroelectric plant later. This also looks costly, and difficult except in hilly country.

Possibly best of all would be heat storage within a pressure tank filled with water and surrounded by a thick envelope of glass wool. The water, heated far above the boiling point, would supply stream for night or cloudy hours.

Doctor Abbot and his automatic solar flash boiler

Commercial Use and Cost of Solar Heating

It is probable that so long as coal is cheap and abundant there will be no extensive use of solar power. However, small installations, in two- to five-horsepower units, may become profitable under favorable conditions. Solar heat has already been used successfully for refrigeration, and possibly might be combined with a heating system for conditioning the air in ranch buildings in cloudless regions. The classic use of solar power is of course for irrigation, and here, as remarked above, the problem of storage is not important. It is conceivable that great reservoirs might be pumped full of water by solar power in dry years to irrigate land when rains fail.

As remarked above, both solar cooking and solar distilling of nonpotable water are practical and efficient propositions, which are likely to be in common use before very long if the necessary outfits can be produced at attractive prices. The cost of solar devices, as of all other products, depends greatly on the volume of sales. As compared with automobiles, however, these devices are extremely simple. Though the cost of producing them singly might be prohibitive, by thousands I do not think it would. In illustration I may say that there is a skilled glass and electrical technician at the Smithsonian Institution who could make, I believe, an excellent Mazda incandescent lamp. I suppose it would cost $25.00. But such is the efficiency of wholesale production that one buys such lamps at the grocery store for 15 or 20 cents apiece. I feel convinced that if some of the solar devices I have described were in wholesale production they could be sold at such low prices as to reach a wide demand.

Terminal Voltage Versus Field Current

Calculation of Curves for Various Overexcited Power Factors

SHERWIN H. WRIGHT
MEMBER AIEE

HAVING the no-load and zero-power-factor (overexcited) saturation curves (figure 1) of a synchronous machine and wanting to construct curves of terminal voltage versus field current for various operating power factors, most engineers will take in hand a bow compass and an engineer's scale and proceed by means of a graphical method to compute various points through which a curve can be plotted. What is believed to be a much simpler method of determining these curves is the one utilizing the curves in figure 2. The procedure is: (1) For any chosen field current read the voltages on the zero-power-factor curve and the no-load saturation curve and compute their ratio; (2) enter figure 2 with this ratio and read the corresponding ratio of terminal voltage to no load voltage; (3) obtain terminal voltage by multiplying the no-load voltage by the quantity read from figure 2.

To illustrate the use of the curves in figure 2, consider the synchronous generator whose no-load and zero-power-factor saturation curves are given in figure 1, and suppose

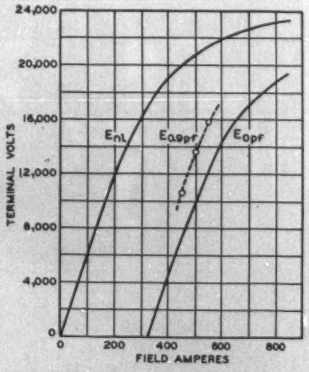


Figure 1. Typical no-load and zero-power-factor saturation curves

E_{nl}—no load

E_{opf}—zero power factor, full load

$E_{0.9pf}$—0.9 power factor, full-load kilovolt-amperes (calculated)

it is desired to plot the curve of terminal voltage versus field current for 0.9 lagging power factor. To obtain one point suppose we choose a field current of 500 amperes. The zero-power-factor voltage, E_{opf} = 10,000 volts, the no-load voltage E_{nl} = 20,800 volts, and the ratio is 0.480. From the 0.9-power-factor curve in figure 2 we read that the ratio of terminal voltage to no-load voltage E_t/E_{nl} = 0.655, and hence terminal voltage E_t = 0.655, E_{nl} = 0.655 (20,800) = 13,700 volts; this then is the terminal voltage for a field current of 500 amperes and 0.9 power factor lagging at full-load kilovolt-amperes. A second point similarly computed for 450 field amperes is 10,700 volts and a third point at 550 field amperes is 15,800 volts, all for 0.9 power factor. A check of these particular values, as well as experience with this method, indicates that in general the accuracy of the results is quite satisfactory and is better than that obtained by the graphical method.

What is perhaps the most commonly used method of solving for terminal voltage (or solving for load field current as it is sometimes expressed) is by means of what is aptly called the "adjusted synchronous reactance" method which is empirical (see AIEE Test Code for Synchronous Machines, paragraph 145, now in report form); in this it is considered that for a given magnitude of armature current and any one value of field current, the synchronous reactance drop is a constant equal to the vertical intercept between the no-load and zero-power-factor saturation curves. While other empirical methods often are employed (see Test Code for Synchronous Machines, paragraph 150, or the new Standards *C*-50 of the American Standards Association) the adjusted synchronous reactance method will probably continue to be used widely. The curves in figure 2 afford a simplified means of applying this "adjusted synchronous reactance" method, and they make a bow compass and scale unnecessary; if a slide rule

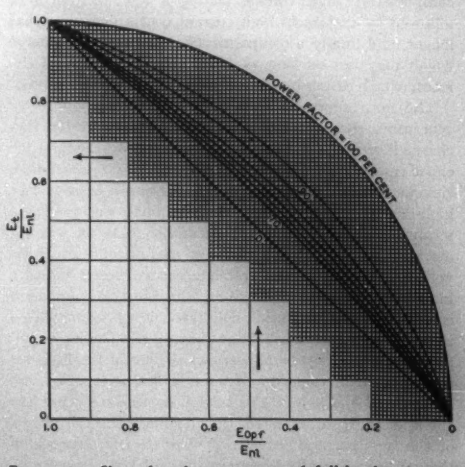


Figure 2. Chart for determination of full-load saturation curves at various power factors by "adjusted synchronous reactance" method

SHERWIN H. WRIGHT is central station engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

is used in conjunction with these curves, the solution is simpler, of engineering accuracy, and usually more accurate than by means of the graphical construction involving a bow compass.

The manner in which the curves were developed may be

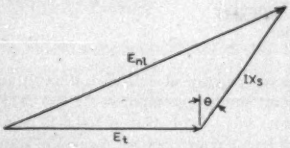


Figure 3. Vector diagram illustrating basis of "adjusted synchronous reactance" method

of interest. In figure 3 the known quantities are the power factor, cos θ, the synchronous reactance drop (IX_s), and the internal no-load voltage, E_{nl}. The terminal voltage E_t is sought, and simple trigonometric relations were derived to give E_t as a function of θ, (IX_s), and E_{nl}. For simplification E_t and (IX_s) were expressed as per-unit values of E_{nl} (merely by dividing by E_{nl}). To determine (IX_s) it would be necessary to subtract (1) the voltage on the zero-power-factor curve from (2) the voltage on the no-load saturation curve, but the need of determining (IX_s) was eliminated by making use of the relation $(IX_s)/E_{nl} = (E_{nl} - E_{znf})/E_{nl} = 1 - E_{znf}/E_{nl}$. Merely reversing the horizontal scale so as to read 0 to 1.0 from left to right would make it possible to use (IX_s) as an index for entering the curve. The curves themselves are merely portions of ellipses; for zero power factor the curve is a straight line, and for unity power factor it is a circular arc.

New Forms and Uses of Laboratory-Created Lightning

RECENT demonstrations of artificial lightning showed two significant developments. The first is the use in factory production-line tests of the high-voltage high-current surge generator; the second is the achievement in the laboratory of so-called "hot" lightning, which has all the components of natural lightning. The demonstrations were made by the Westinghouse Electric and Manufacturing Company at Sharon, Pa., where the surge generator is being used to test distribution transformers of the completely self-protected type. The generator which produces the "hot" lightning is being used in the company's research laboratories.

Natural lightning may be said to have three separate components: high voltage lasting a few microseconds, followed by extremely high current continuing somewhat longer, and finally a comparatively low-current discharge which may last as long as a full second. The final element, which causes burning, is the latest to be reproduced.

The first laboratory-made lightning was produced by generators that created a high-voltage low-current discharge lasting a few microseconds and lacking much of the effect caused by the combination of high voltage and high current in natural lightning. In creating a high-voltage high-current generator, the chief problem was to find a means of joining the two elements, so that the current discharge would be released a few microseconds after the voltage discharge. The problem was solved by a device known as a microsecond switch, which in this application is a fiber tube with a small hole through its center, placed in series with the high-voltage generator. The high temperature caused by breakdown of the air in the hole vaporizes a small quantity of fiber, which is expelled violently from the hole. The tube is so mounted that the gas is discharged across the gap holding back the charge of the high-current generator. The electric strength of the gap is sufficiently lowered to permit the current generator to release its charge into the lightning circuit.

An important laboratory tool for testing purposes, the high-voltage high-current surge generator has now become a production tool in the factory. The generator used for this purpose, as shown in the illustration, consists of an upper bank of 15 capacitors that can produce a surge of 1,500,000 volts per microsecond, and a lower bank of 32 that can develop a discharge of 100,000 amperes.

News

Of Institute and Related Activities

New AIEE Officers Elected at Summer and Pacific Coast Convention

AT THE annual meeting of the AIEE, held during the combined summer and Pacific Coast convention of the Institute, just concluded, the committee of tellers presented its report on the election of new officers for the year beginning August 1, 1939. The new officers elected are:

President: F. M. Farmer, vice-president and chief engineer, Electrical Testing Laboratories, New York, N. Y.

Vice-Presidents: C. T. Sinclair, electrical engineer, transmission and distribution, Duquesne Light Company, Pittsburgh, Pa. (Middle Eastern District, number 2); E. E. George, superintendent of system operation, Tennessee Electric Power Company, Chattanooga (Southern District, number 4); A. L. Turner, chief engineer, Northwestern Bell Telephone Company, Omaha, Nebr. (North Central District, number 6); H. W. Hitchcock, chief engineer, Southern California Telephone Company, Los Angeles, Calif. (Pacific District, number 8); J. M. Thomson, chief designing engineer, Ferranti Electric, Ltd., Toronto, Ont., Canada (Canadian District, number 10).

Directors: Mark Eldredge, chief engineer, Memphis Power and Light Company, Memphis, Tenn.; R. E. Hellmund, chief engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.; F. J. Meyer, vice-president in charge of operation, Oklahoma Gas and Electric Company, Oklahoma City.

National Treasurer: W. I. Slichter, professor of electrical engineering and head of department, Columbia University, New York, N. Y.

The board of directors for the administrative year beginning August 1, 1939, will consist of these newly elected officers, together with the following holdover officers: J. C. Parker (retiring president) New York, N. Y.; W. H. Harrison (junior past-president) New York, N. Y.; K. B. McEachron, Pittsfield, Mass.; C. A. Powel, East Pittsburgh, Pa.; R. W. Sorensen, Pasadena, Calif.; C. R. Beardsley, New York, N. Y.; Vannevar Bush, Washington, D. C.; F. H. Lane, Chicago, Ill.; L. R. Mapes, Chicago, Ill.; H. S. Osborne, New York, N. Y.; D. C. Prince, Philadelphia, Pa.; C. L. Dawes, Cambridge, Mass.; A. H. Lovell, Ann Arbor, Mich.; F. C. Bolton, College Station, Tex.; L. R. Gamble, Spokane, Wash. A vice-president from New York City District, number 3, to fill the vacancy left by the election of F. M. Farmer as president, will be elected by the board of directors, as provided in the constitution.

At the general session of the convention June 28, A. S. Bennion, assistant to the president, Utah Power and Light Company, Salt Lake City, gave an address on "Human Relationships." A detailed account of the convention is scheduled for the August issue.

Members of AIEE Los Angeles Section Visit Aqueduct

AS GUESTS of the Metropolitan Water District of the City of Los Angeles, Calif., more than 70 members of the AIEE Los Angeles Section recently inspected the metropolitan aqueduct pumping plants at Parker Dam, 300 miles from Los Angeles. The aqueduct, a $200,000,000 project and one of the largest undertakings of the kind in the world, will have a total capacity of approximately 1,500 cubic feet of water per second. The visitors, who are shown in the illustration, inspected the five pumping stations of the project under the guidance of J. M. Gaylord (A'07, F'35), chief electrical engineer, Metropolitan Water District, and secretary-treasurer of the Los Angeles Section. A group of 400 members and friends of the Los Angeles and San Diego Sections on May 20, 1939, attended a picnic at Palomar Mountain, Calif., where they inspected the dome and mounting of the 200-inch telescope now under construction.

AIEE Board of Directors Meets at Institute Headquarters

THE regular meeting of the board of directors of the AIEE was held at Institute headquarters, New York, N. Y., May 26, 1939.

Present: *President*—John C. Parker, New York, N. Y. *Past-Presidents*—W. H. Harrison, New York, N. Y.; A. M. MacCutcheon, Cleveland, Ohio. *Vice-Presidents*—C. L. Dawes, Cambridge, Mass.; F. M. Farmer, New York, N. Y.; A. H. Lovell, Ann Arbor, Mich.; M. J. McHenry, Toronto, Ont.; I. Melville Stein, Philadelphia, Pa.; Edwin D. Wood, Louisville, Ky. *Directors*—C. R. Beardsley, C. R. Jones, H. S. Osborne, New York, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; K. B. McEachron, Pittsfield, Mass.; C. A. Powel, East Pittsburgh, Pa.; D. C. Prince, Philadelphia, Pa.; R. W. Sorensen, Pasadena, Calif. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y.

Minutes of meetings of the board of directors held January 24, 1939, and the executive committee March 6, 1939, were approved.

Executive committee action on applications, under dates of March 21, April 11, and April 25, 1939, was reported, and confirmed by the Board, as follows: 2 applicants transferred to the grade of Fellow; 16 applicants transferred and 31 elected to the grade of Member; 647 applicants elected to the grade of Associate; 219 Students enrolled.

Reports of meetings of the board of examiners held March 16, April 20, and May 18, 1939, were presented and approved. Upon the recommendation of the board of examiners, the following actions were taken: 3 applicants were transferred to the grade of Fellow; 14 applicants were transferred and 13 elected to the grade of Member; 1 applicant was reinstated to the grade of Member; 366 applicants were elected to the grade of Associate; 156 Students were enrolled.

F. V. Magalhaes, Harold Goodwin, Jr., and H. E. Farrer were appointed as representatives of the board of examiners to co-operate with the committee on professional recognition of the Engineers' Council for Professional Development in a study of qualifications for the various grades of membership in engineering societies.

Monthly disbursements were reported by the finance committee, and approved by the board of directors, as follows: $19,390.43 in March, $23,293.15 in April, and $32,258.80 in May.

Amendments to the Institute bylaws were adopted, as indicated: Sections 45, 46, and 47 amended to read as follows:

Sec. 45. Speakers at Section and Branch meetings may present informal talks with or without notes or may present formal papers in full or in abstract from prepared manuscripts. Only the latter are designated as *papers* in these bylaws.
Section officers should endeavor to include a number of formal papers in each year's program, so that, through publication in ELECTRICAL ENGINEERING, a substantial number of high quality Section papers may be made available to the whole membership.

Sec. 46. Section and Branch officers shall be responsible to the Institute for all Section and Branch papers and any recorded discussion of them. Such papers shall not be released for publication in advance of presentation and except as a news item, the name of the Institute shall not be used in connection with their publication unless authorized by the publication committee.
Section and Branch officers should make a reasonable effort to obtain the manuscripts of papers at the time of presentation, and these should be forwarded promptly to the national secretary, with such recommendations as the Section and Branch officers wish to make with reference to publication.

Sec. 47. Except as a news item, the name of the Institute shall not be used in connection with the publication, elsewhere than in ELECTRICAL ENGINEERING, of subject matter presented as an informal talk before a Section or Branch meeting.
Where publication in TRANSACTIONS of Section or Branch papers by non-members of the Institute is involved, approvals shall be obtained in accordance with section 95 of the bylaws.

Section 98 amended to read:

Sec. 98. No paper or address approved by the technical program committee for presentation at a national convention or District meeting, or any written contribution to a discussion thereon, shall be released for publication in advance of presentation except by authority of the board of directors. An informal address or technical paper not approved by the technical program committee for presentation, but included in the program of a District meeting, shall not be released for publication in advance of presentation. The name of the Institute shall not be used in connection with the publication of the subject matter of such an address or paper except in ELECTRICAL ENGINEERING, or in news items elsewhere, unless authorized by the publication committee.

Section 85, fifth paragraph, changed to read as follows:

Each technical committee shall, from time to time, as determined in co-operation with the technical program committee, present at a national meeting of the Institute a report including a brief résumé of the progress of the art in the particular field within the scope of such committee, with the object that these reports may be authoritative sources of information on the history of electrical engineering development. These reports shall be, whenever practicable, published with discussion.

Section 65, the following paragraph added:

At the close of the fiscal year, each committee shall send to the national secretary a report of its activities.

The board confirmed the appointment by the president of the following committee of tellers to canvass, count, and report upon the ballots cast for the 1939 election of Institute officers: E. Curtis Plant, *chairman*, R. W. DeMonte, F. W. Engster, E. T. Farish, W. N. Goodridge, John V. Moses, and E. Volckmann.

A revision of the manual of the technical program committee was approved and its publication authorized. This contains information ordinarily needed by members of the technical program committee, technical committees, and District committees in connection with the handling of national conventions and District meetings of the Institute.

Upon recommendation of the Institute policy committee, the board rescinded the action of the board of directors on January 22, 1934, in ruling "that the subject of depreciation of electrical machinery is considered not within the province of the Institute," and adopted a statement of policy to the effect that meetings of the Institute are open for the presentation of papers on the subject of depreciation, written from an engineering approach, if Institute members desire to submit such papers to the technical program committee for consideration, in accordance with the prescribed procedure for scheduling papers for Institute meetings.

As recommended by the standards committee, it was voted that the AIEE undertake sponsorship of a sectional committee on sphere-gap standards to develop further the standards which have been evolved by a subcommittee of the committee on instruments and measurements, the subcommittee to become a part of the proposed sectional committee. F. T. McNamara was appointed AIEE representative on the sectional committee on radio-electrical co-ordination—C65, to succeed R. G. Warner, resigned.

The establishment of a Student Branch of the Institute at the University of Alberta, Edmonton, Alberta, Canada, was authorized.

Chairman F. M. Farmer presented a report of the committee on planning and co-ordination, which dealt with the assignment to "study the present policy and activities of the Institute and recommend to the board of directors such changes and expansions as it may conclude will best meet the appropriate needs of the membership as a whole and make the Institute more useful to the profession." The following recommendations of the committee were approved by the board:

DISCUSSIONS OF SOCIAL AND ECONOMIC QUESTIONS

1. That the present general policy with respect to this matter be continued.

2. That, in discussing with the Sections their local affairs, it be pointed out that their meetings are informal and that, therefore, there is no requirement for any restriction in the discussions of these subjects.

3. That the forum of the Institute and its publications should be open to comment on public questions involving engineering, particularly large-scale engineering enterprises of government, provided that such comment is limited strictly to engineering and associated facts.

PRESENTATION AND PUBLICATION OF PAPERS

1. That the attention of the program committees for District and even Section meetings be called to the availability of national meeting papers for re-presentation at local meetings. This was a

Future AIEE Meetings

Great Lakes District Meeting
Minneapolis, Minn., September 27–29, 1939

Middle Eastern District Meeting
Scranton, Pa., October 11–13, 1939

Winter Convention
New York, N. Y., January 22–26, 1940

Summer Convention
Swampscott, Mass., June 24–28, 1940

Pacific Coast Convention
Vancouver, B. C., August 27–30, 1940

common practice when the first Sections were organized, and is still the custom in The Institution of Electrical Engineers (British).

2. That special efforts be made to get more papers in the transportation, lighting, marine, industrial, and other special fields, in order to retain as much interest as possible in the Institute as *the* organization of the electrical engineering profession as a whole.

Actions were taken on recommendations of the committee on the following subjects, as indicated:

RESEARCH

1. Postponed to a future meeting consideration of a recommendation for reviewing the proposal to make the committee on research a general committee instead of a technical committee, which has been before the board of directors on two previous occasions.

2. Approved the recommendation that consideration be given to including in the budget for the next appropriation year contributions to projects which the Institute is sponsoring under The Engineering Foundation.

NOMINATIONS PROCEDURE

Approved recommendations that the national secretary urge the members of the national nominating committee to submit to him suggestions for president and for directors; and that the board of directors, when designating its five members of the nominating committee, include at least one who has previously served in that capacity. Another recommendation on this subject was referred to the Institute policy committee.

It was decided that the remainder of the report, dealing with topics on which no recommendations were submitted by the committee, would be scheduled for a subsequent meeting of the board, the president, in the meantime, at his discretion to refer any or all of these topics to either regular or special committees for further study and report.

The board confirmed the application of the Institute, upon the recommendation of the committee on research, to The Engineering Foundation for the continuance next year of support of the work of the welding research committee.

The national secretary submitted a draft of the annual report of the board of directors for the fiscal year ending April 30, 1939, which he had prepared, for approval for presentation at the annual meeting of the Institute to be held in San Francisco, Calif., June 26. The report of the national treasurer for the same period was also presented.

In accordance with article VII, section 37, of the constitution, consideration was given to the appointment of a national secretary for the year beginning August 1, 1939, and National Secretary H. H. Henline was reappointed.

H. B. Gear was reappointed a representative of the Institute on the Washington Award Commission for the two-year term beginning August 1, 1939. The president was authorized to appoint a representative on the board of trustees of the United Engineering Trustees, Inc., for the four-year term beginning in October 1939.

An invitation to be represented at the celebration, November 11–13, 1939, of the semicentennial of the Catholic University of America, was accepted, with the understanding that the appointment of the representative would be made after the new administration is in office.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

Additions to List of Members for Life

Membership for life is granted by the AIEE to members who have either paid annual dues for 35 years, or have reached the age of 70 and have paid dues for 30 years. A list of those who have become members for life during the preceding year is published annually in ELECTRICAL ENGINEERING. The following are the Institute members who have reached member-for-life status since publication of the last previous list in the July 1938 issue.

F. B. Adam
F. J. Adams
E. F. W. Alexanderson
Harry Allcock
C. E. Allen
E. G. Allen
H. R. Allensworth
G. A. Anderegg
A. O. Austin
I. F. Baker
L. W. Bates
W. V. Batson
B. B. Beckett
Sven R. Bergman
N. S. Braden
Graham Bright
H. B. Brooks
A. E. Brown
J. M. Bryant
G. A. Burnham
John Campbell
C. E. Canfield
A. R. Cheyney
B. C. Condit
A. W. Copley
J. B. Cox
W. M. Dann
G. S. Davis
J. M. Donaldson
Lee De Forest
E. A. Ekern
Richard Eyre
F. L. Francisco
W. R. Garton
C. H. Gilbert
W. T. Goddard
R. H. Goodwillie
A. G. Grier
C. E. Hall
W. A. Hall
Dean Harvey
V. Hayden
W. Hemphill
T. Hibbard
W. E. Holland
F. W. Huels
S. R. Inch
L. T. Kaiser
O. F. Kern
C. F. Kettering
C. J. Kiefer
C. W. Koiner
A. C. Lanier
H. N. Latey
P. Lebenbaum
M. J. Levy
A. D. T. Libby
F. A. Lindberg
D. L. Lindquist
P. MacGahan
M. P. MacKay
M. MacLaren
R. H. Marvin
J. E. Mateer
W. McClellan
B. T. McCormick
R. McCulloch
F. C. McNulty
F. A. Merrick
A. S. Miller
W. J. Mowbray
Paul J. Myler
N. E. Newton
R. H. Nexsen
L. C. Nicholson
L. D. Nordstrum
W. J. Norton
I. Notomi
E. B. Paine
J. C. Parker
A. E. Peirce
J. W. Perry
G. G. Ponti
H. W. Price
E. J. Prindle
H. Rawson
R. H. Rice
C. W. Ricker
S. Howard Rippey
Julian Roe
G. A. Sawin
C. J. Schaus
D. F. Schick
C. A. Schneider
E. H. Schwarz
J. H. Siegfried
A. B. Smith
J. C. Smith
G. Staunton
G. F. Steele
Cabot Stevens
R. J. Strike
E. D. Swinburne
H. B. Van Etten
E. B. Walker
H. B. Waters
Burr Wheeler
F. W. Willis
C. H. Wright
R. I. Wright
H. Wurdack
J. W. Young
G. J. Yundt

Great Lakes District Meeting to Be Held in Minneapolis

The Great Lakes District, AIEE, will hold a three-day meeting and Student Branch convention in Minneapolis, Minn., September 27–29, 1939. Headquarters for the meeting will be in the Hotel Nicollet.

Minneapolis, gateway to the land of 10,000 lakes, is termed the commercial, financial, educational, and cultural center of the Northwest. Among features of interest to visitors may be mentioned the flour mills located on the Mississippi River at St. Anthony Falls, the University of Minnesota, the Minneapolis Symphony Orchestra, the Minneapolis boulevard and Park systems, historic Fort Snelling, the "Twin City" of St. Paul, Lake Minnetonka, and Minnehaha Falls. Transportation facilities to the Twin Cities are modern and convenient.

An attractive program of technical sessions, inspection trips, entertainment, and sports is offered. Tentative plans call for five technical sessions and two student

Meeting headquarters will be at Hotel Nicollet, Minneapolis, Minn.

sessions. In scheduling papers for the former the varied interests of engineers have been carefully considered. The detailed program will be announced later.

Members of the District Meeting committee are: C. E. Nelson, *chairman*; J. M. Bryant, R. E. Burlingame, E. G. Hagensick, and chairmen of the subcommittees: I. B. Garthus, meetings and papers; H. W. Meyer, entertainment; E. G. Hagensick, transportation and inspection; J. H. Kuhlmann, student sessions; Truman Hibbard, finance; Allen Dewars, publicity; Mrs. H. W. Meyer, ladies' entertainment; and R. E. Burlingame, hotels and registration.

Middle Eastern District to Meet in Scranton, Pa.

The Lehigh Valley Section of the AIEE will be host to a three-day meeting of the Middle Eastern District, to be held in Scranton, Pa., October 11–13, 1939, with the meeting headquarters in the Hotel Casey.

The general committee, of which E. F. DeTurk of Reading is chairman, recently appointed the following committee chairmen: M. O'Toole, entertainment and reception; W. H. Lesser, transportation and inspection trips; J. W. Mills, hotels and reservations; G. E. Northup, publicity and attendance; J. G. Charest, meetings and papers; N. S. Hibshman, student sessions; and E. F. Weaver, finance.

The tentative program will include nine technical sessions, five inspection trips, reception and entertainment, informal dinner-dance, with social events and inspec-

tion trips being arranged for the women guests by Mrs. G. E. Northrup, chairman of the women's committee.

The Lehigh Valley Section of the AIEE includes, among others, the cities of Wilkes-Barre, Hazleton, Easton, Bethlehem, Allentown, Reading, Sunbury, and Williamsport. The Middle Eastern District includes Philadelphia, Pittsburgh, and Erie, Pa., Washington, D. C., Baltimore, Md., Charleston, W. Va., and Cleveland, Columbus, Toledo, and Akron, Ohio. This is the second occasion upon which the Lehigh Valley Section has been host to the Middle Eastern District, the first being in April 1927, at Bethlehem, Pa., with 400 in attendance. It is estimated that the Scranton meeting will have a registration of 350.

Stoekle Fellowship Fund. The Engineers Society of Milwaukee, Wis., with which the AIEE Milwaukee Section is affiliated, has been made trustee of a fund for a fellowship in memory of Doctor E. R. Stoekle (M'17, F'33), vice-president of Globe-Union, Inc., who died March 14, 1938. The fund provides for an annual grant of up to $400. Beneficiaries, to be selected by the scholarship committee, must be graduates of a secondary school in the County of Milwaukee, and residents of the county at the time of graduation. As the award is not limited to recent graduates, students of science and engineering schools are eligible.

Research Group Visits Laboratories. Members and guests of the Industrial Research Institute, an affiliate of the National Research Council formed last year to exchange ideas on laboratory management, made a tour of industrial laboratories May 16–20, 1939. The trip included visits to the laboratories of the Hoover Company, Canton, Ohio, the Jones and Laughlin Steel Corporation, Pittsburgh, Pa., and the Hercules Powder Company, Wilmington, Del., and ended with meetings at the National Academy of Science, Washington, D. C.

Future Meetings of Other Societies

American Institute of Mining and Metallurgical Engineers. 151st general meeting, July 10–13, San Francisco, Calif.

American Society of Civil Engineers. Annual convention, July 26–29, San Francisco, Calif.

American Society of Heating and Ventilating Engineers. Semiannual meeting, July 4–6, Mackinac Island, Mich.

American Society of Mechanical Engineers. Semiannual meeting, July 10–15, San Francisco, Calif.

Fall meeting, September 4–8, New York, N. Y.

Joint meeting ASME Fuels Division, AIME Coal Division, October 5–7, Columbus, Ohio.

Illuminating Engineering Society. 33d annual convention, August 21–25, San Francisco, Calif.

Institute of Radio Engineers. 14th annual convention, September 20–23, New York, N. Y.

National Electrical Contractors Association. October 9–12, Philadelphia, Pa.

National Electrical Manufacturers Association. October 23–27, Chicago, Ill.

National Safety Council. October 16–20, Atlantic City, N. J.

Society of Automotive Engineers. Tractor meeting, September 28–29, Detroit, Mich.

National aircraft production meeting, October 5–7, Los Angeles, Calif.

Transportation and maintenance meeting, October 26–27, St. Louis, Mo.

Standards

Co-ordination of Reference Values in Institute Standards

Continuing the series of articles begun several months ago on the standards work of the AIEE, this month's item calls attention to a lack of co-ordination of reference values in AIEE standards, and announces the appointment of a subcommittee by the chairman of the standards committee to co-ordinate reference values. It was prepared by J. Franklin Meyer, physicist, National Bureau of Standards, Washington, D. C., and chairman of the new subcommittee.

Although the Institute has been making standards for many years and although these standards have been widely accepted in the electrical industry, there has been little or no concentrated effort on the part of the standards committee nor on the part of any of the technical committees to co-ordinate differences that exist in the Institute standards. This lack of uniformity in what may be called "reference values" such as temperatures, pressures, humidities, altitudes, etc., detracts from the usefulness of the standards and may result in misunderstandings and consequent confusion.

Chairman R. E. Hellmund of the standards committee has taken cognizance of these conditions and has appointed a number of subcommittees to attempt to improve the existing situation. Among the subcommittees appointed is one to study "reference values for standards." In addition to the chairman, this subcommittee consists of the chairmen of the Institute's technical committees, or a representative appointed by the chairman of a particular technical committee, and the following additional persons: P. L. Bellaschi of the Westinghouse Electric and Manufacturing Company, Sharon, Pa.; I. Melville Stein of Leeds and Northrup Company, Philadelphia, Pa.; P. L. Alger of the General Electric Company, Schenectady, N. Y.; and F. M. Farmer of Electrical Testing Laboratories, New York, N. Y.

The chairmen of the various technical committees of the Institute, being more familiar with the details of the AIEE standards in their respective fields than any one else, will be asked to furnish for the use of the committee detailed information on the "reference values" used in these standards.

Other members of the subcommittee have first-hand knowledge of reference values as they now exist in practice and in standards of other organizations, both national and international. All this material will be cumulated and later analyzed, so that a complete summary may become available and perhaps published in a later issue of ELECTRICAL ENGINEERING. The co-operation of all interested engineers is invited.

American Engineering Council

Personnel Changes in SEC

To take the place of former chairman William O. Douglas, now a member of the Supreme Court, President Roosevelt has appointed as member of the Securities and Exchange Commission Leon Henderson, who had been executive secretary of the Temporary National Economic Committee. As soon as Mr. Henderson was sworn in the SEC members, by a vote of 3 to 2, elected Jerome Frank as their new chairman. Both men are ranked as ardent supporters of President Roosevelt so the conduct of SEC policies will continue along the lines laid out under the chairmanship of Mr. Douglas.

Besides its supervision over stock exchanges and security issues, the SEC is charged with the enforcement of that part of the Public Utilities Holding Company Act dealing with the simplification of corporate structures in the utilities field. Chairman Frank announced, shortly after his election, that the SEC will shortly begin conferences with utility executives for the consideration of reorganization plans submitted last December, and since then under study by the SEC staff.

McClellan Heads Union Electric

William McClellan (A'04, F'12), president of American Engineering Council and past-president of the AIEE, has resigned as president of the Potomac Electric Power Company, Washington, D. C., to become the head of the Union Electric Company of Missouri, with headquarters in St. Louis. Both companies are subsidiaries of the North American Company.

This move took place as the result of a complaint by the Securities and Exchange Commission that the Union company had made political campaign contributions in violation of law. President Louis H. Egan (A'08, M'15) and Vice-Presidents Frank J. Boehm (M'25) and Albert C. Laun of the Union Electric Company resigned pending the investigation of the charges. The two vice-presidents were replaced by Edward T. Gushee, vice-president of the Detroit Edison Company, and John A. Woodbridge, of the law firm of Sullivan & Cromwell, counsel for the North American Company.

Report of the Board of Directors

THE board of directors of the American Institute of Electrical Engineers presents herewith to the membership its 55th annual report, for the fiscal year ending April 30, 1939. A general balance sheet showing the condition of the Institute's finances on April 30, 1939, together with other detailed financial statements, is included herein. This report contains a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in ELECTRICAL ENGINEERING.

BOARD OF DIRECTORS' MEETINGS

During the year, the board of directors held five meetings, four in New York City, and one in Washington, D. C. The executive committee meetings in December and March were held in place of regular meetings of the board. Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and the committees is published each month in the section of ELECTRICAL ENGINEERING devoted to "News of Institute and Related Activities."

PRESIDENT'S AND NATIONAL SECRETARY'S VISITS

President Parker and Secretary Henline attended the Pacific Coast and winter conventions, the Southern District meeting in Miami, and the South West District meeting in Houston, Texas. They also visited many Sections and Student Branches. During May and June, they will attend the North Eastern District meeting in Springfield, Mass., and the combined Summer and Pacific Coast convention in San Francisco, Calif. Visits will be made to the following Sections: Cincinnati, Cleveland, Erie, Mansfield, Rochester, Toledo, and Worcester.

The places visited by President Parker are listed below:

Alabama
Joint meeting Alabama, East Tennessee, Memphis, and Muscle Shoals Sections, Huntsville
Alabama Section, Birmingham
University of Alabama Branch

Colorado
Denver Section

District of Columbia
Conference on student activities, District No. 2
Washington Section
American Engineering Council

Florida
Southern District meeting, Miami

Georgia
Georgia Section, Atlanta

Illinois
Chicago Section

Louisiana
New Orleans Section
Tulane University Branch

Maryland
Baltimore and Washington Sections, joint meeting, Baltimore
Johns Hopkins University Branch, and representatives of Catholic University of America, George Washington University, and University of Maryland Branches, Baltimore

Massachusetts
Boston Section
Worcester Section
Worcester Polytechnic Institute
Massachusetts Institute of Technology Branch and representatives of Tufts, Northeastern, and Harvard University Branches, Cambridge

Michigan
Michigan Section, Detroit
University of Michigan Branch

Missouri
Kansas City Section
St. Louis Section

Nebraska
Nebraska Section, Omaha

New York
New York Section
Winter convention

Oregon
Pacific Coast convention, Portland

Pennsylvania
Philadelphia Section
Pittsburgh Section (jointly with neighboring Branches)

Tennessee
Memphis Section

Texas
South West District meeting, Houston

Utah
Utah Section, Salt Lake City

Virginia
Virginia Section, Richmond
Virginia Military Institute Branch
Virginia Polytechnic Institute Branch
University of Virginia Branch

Canada
Annual meeting, Engineering Institute of Canada, Ottawa

The places visited by the national secretary are the following:

Arkansas
University of Arkansas Branch

District of Columbia
Conference on student activities, District No 2
Washington Section
American Engineering Council

Florida
Southern District meeting, Miami

Georgia
Georgia Section, Atlanta

Kansas
Wichita Section

Kentucky
Louisville Section
University of Kentucky Branch

Maryland
Baltimore and Washington Sections, joint meeting, Baltimore
Johns Hopkins University Branch, and representatives of Catholic University of America, George Washington University, and University of Maryland Branches, Baltimore

Massachusetts
North Eastern District executive committee meeting, Pittsfield

New York
New York Section
Winter convention

Oregon
Pacific Coast convention, Portland

Pennsylvania
Philadelphia Section

Texas
South West District meeting, Houston
San Antonio Section

Virginia
Virginia Section, Richmond
Virginia Military Institute Branch
Virginia Polytechnic Institute Branch
University of Virginia Branch

Canada
Annual meeting, Engineering Institute of Canada
Ottawa

NATIONAL CONVENTIONS

Three national conventions were held during the year, and a brief report on each follows:

Summer Convention. The 54th summer convention was held in Washington, D. C., June 20–24, 1938. In addition to the annual business meeting, conference of officers, delegates, and members, a conference of vice-presidents, district secretaries, and counselor delegates, there were 10 technical sessions, at which 48 papers were presented, one general session, and six conference sessions. The general session consisted of addresses by President W. H. Harrison, Dr. W. R. Gregg, chief of the weather bureau, and Colonel J. M. Johnson, assistant secretary of commerce.

Entertainment features of the convention were a luncheon, dance, banquet, at which the Gaston Plante Medal and 4,500-franc prize was presented to Dr. G. W. Vinal, tea, golf and tennis tournaments. The registration was 825.

Annual Meeting. The annual business meeting of the Institute was held on Tuesday morning, June 21. The annual report of the board of directors for the fiscal year which ended April 30, 1938, was presented in abstract by the national secretary. A report on the finances of the Institute was presented by National Treasurer W. I. Slichter. The report of the committee of tellers upon the election of officers for the year beginning August 1, 1938, was presented, and President-Elect Parker responded to his introduction with a brief address. During this session, the Lamme Medal for 1937 was presented to Dr. R. E. Doherty, president, Carnegie Institute of Technology, Pittsburgh, Pa.

Pacific Coast Convention. The 26th Pacific Coast convention was held in Portland, Oregon, August 9–12, 1938, with a registration of 454. Five technical sessions, including 22 papers, two student technical sessions, a general session, a joint conference on student activities, reception and dancing, buffet supper, banquet, inspection trips, golf tournament, and ladies' events constituted the principal features of the convention. A technical session on communication was held jointly with the Institute of Radio Engineers.

Winter Convention. The 27th winter convention was held in New York City, January 23–27, 1939, with a program including 77 papers in 17 technical sessions, two general sessions, and 5 technical conferences. During a general session on Wednesday morning, a brief address was given by President Parker, and Dr. Virgil Jordan, president of the National Industrial Conference Board, Inc., gave an address on "Enterprise and Social Progress." A second general session on Thursday afternoon was devoted to engineering conclusions drawn from the experiences encountered during the New England hurricane of September 21, 1938. The 6 speakers in-

cluded American Red Cross, railroad, power utility, and telephone representatives.

At an evening session, the Edison Medal was presented to Past-President Dugald C. Jackson, and the John Fritz Medal was presented to Past-President F. B. Jewett.

A smoker, numerous inspection trips, and ladies' events completed the program of the convention, which had a registration of 1,610, the largest since 1924.

District Meetings

Brief reports on the three District meetings held during the year are given below:

North Eastern District Meeting. This meeting was held in Lenox, Mass., May 18–20, 1938, with 3 technical sessions, at which 13 papers were presented, one session for student papers, and a general session with addresses by Roger Babson and K. K. Darrow, an informal banquet, stag smoker, District conference on student activities, inspection trips, and ladies' events. The registration was 417.

Southern District Meeting. This meeting was held in Miami, Florida, November 28–30, 1938, with 4 sessions, at which 10 papers and 4 addresses were presented, and a student session. A conference on student activities, inspection trips, banquet and dance, and ladies' events were included in the program. The registration was 258.

South West District Meeting. The meeting of this District was held in Houston, Texas, April 17–19, 1939, with 5 technical sessions, at which 15 papers and one address were presented, 2 symposiums, and 3 additional sessions for the presentation of 14 student papers, a dinner dance, inspection trips, sports, and ladies' events. The registration was 536.

Sections

Organization of the San Diego and Mansfield Sections, in January and March, respectively, brought the total number to 67. Beginning activities late in 1938 as the Mansfield division of the Cleveland Section, the members in that vicinity soon aroused much interest and secured many new members. The formation of a Section was authorized by the Institute executive committee on March 6.

All of the Sections have been active, and the total number of meetings reported to headquarters was 635, a slight increase over the 624 for the preceding year, and the 621 for 1936–37. The latter was far larger than the highest previous number, 540.

The name of the Detroit-Ann Arbor Section was changed to Michigan Section, with no change in territory.

Interest in the activities of technical groups within the Sections and in the holding of special technical meetings has continued to expand. Several Sections continued their arrangements for offering courses of instruction desired by their membership. The award of prizes by some Sections and co-operation between Sections and Branches in many localities were continued with good results.

The committee on safety wrote the Sections suggesting that each have presented each year a paper dealing with accident prevention or remedial measures after electrical shock. Replies indicated that many Sections were arranging to carry out this suggestion.

Three topics of current lively interest are before the Sections as was indicated at the meeting of the Sections Committee in New York at the time of the winter convention:

Unassigned Territory. Chairman Race presented a map showing the territories in the United States not now assigned to any Section.

The general policy was endorsed that wherever practicable the members in such territories should receive notices from and be made to feel a part of the Section nearest to them. In large areas such as the states of South Carolina and West Virginia, Sections should be formed as early as there is sufficient local interest and justification.

In smaller areas such as groups of counties in Maine, New Hampshire, Vermont, and Pennsylvania, the chairman was empowered to consult with the vice-president and Section officers concerned to allocate to the nearest Section such auxiliary territory.

On January 9th, President Parker addressed a letter to Institute members in the unassigned territories requesting suggestions as to how the Institute could be of greater service to those individuals who because of location find it difficult to attend Section meetings. The Sections' opportunity in this respect is indicated in the previous discussion.

Section Activities. Chairman Race presented a chart summarizing the information received to date on Section activities in response to his letter of December 27, 1938. The object of this effort is to inform all Sections on the projects that have proved most interesting and helpful. The suggestion has been made that the Sections committee undertake the preparation of a pamphlet summarizing these numerous and diverse activities so as to make available to incoming Section officers the background of experience of all Sections.

Registration of Engineers. Mr. Beardsley reported on the present status of the licensing of professional engineers. He said that the National Council of State Boards of Engineering Examiners had invited the Institute to co-operate in the formulation of examinations for candidates for the license. Also the board of directors of the Institute had authorized funds for the printing and distribution to Section officers of copies of the latest revision of the AIEE model law. Professor Timbie was appointed to represent the Sections committee to assist in this project.

More detailed information on these activities may be found in the annual report on Section and Branch activities in the June issue of Electrical Engineering, pages 268–71.

Table I. Section and Branch Statistics

	For Fiscal Year Ending			
	April 30, 1936	April 30, 1937	April 30, 1938	April 30, 1939
Sections				
Number of Sections	61	62	65	67
Number of Section meetings held	540	621	624	635
Total attendance	85,501	74,950	110,148	85,692
Branches				
Number of Branches	118	119	120	120
Number of Branch meetings held	1,045	1,363	1,334	1,190
Total attendance	45,304	46,121	60,446	53,380

Student Activities

A new Branch organized at the New Mexico State College restored the total number to 120, after the University of North Carolina Branch had been discontinued due to consolidation of the engineering school with that of the North Carolina State College.

Only one Branch failed to report any activity, but the total number of meetings, 1,190, was much lower than in each of the preceding fiscal years, 1,363 in 1936–37, and 1,334 in 1937–38. There was also a material reduction in the number of student talks at Branch meetings.

As indicated in the reports on national conventions and District meetings, the interest in student technical papers has continued, and the following sessions were held: North Eastern District meeting in Lenox, one; Pacific Coast convention, Portland, two; Southern District meeting, Miami, one, and South West District meeting, Houston, three.

With the approval of the committee on Student Branches, the committee on safety again suggested to all counselors that each Branch have presented a paper dealing with the prevention of accidents or remedial measures after electrical shock. Gratifying responses were received from many Branches.

The midwinter meeting of the committee on Student Branches, held January 26th, was attended by 52 members and invited guests. The meeting was made general to include all those present, and business was transacted as reported on page 124 of Electrical Engineering for March. Pursuant to the actions taken at that time, a committee is making good progress in rewriting the pamphlet "The Electrical Engineer," which it is expected will be ready for distribution during the coming summer. Another committee, including A. C. Stevens, chairman, F. C. Caldwell, A. G. Conrad, C. E. Skinner, and C. C. Whipple, is busily engaged in preparing a suitable description of the work of Dr. C. F. Scott, the founder of AIEE Student Branches, which can be used at Student Branch meetings next year to celebrate Dr. Scott's 75th anniversary.

According to records at headquarters, the terms of 1,564 enrolled students were expected to expire on April 30. Applications for admission as Associates were received from 849, or about 54 per cent. Some of

Table II. Technical Programs, Last Two Years

	Year Ending April 30, 1939	Year Ending April 30, 1938
Number of national conventions	3	3
Number of District meetings	3	2
Registration at national conventions and District meetings	4,100	3,587
Number of papers presented	184	184
Number of papers recommended for TRANSACTIONS	169	143
Number of pages required for printing papers in TRANSACTIONS	986*	935
Number of technical sessions	50	43
Number of technical conferences	12	8

* Partly estimated.

the students were eligible to continue enrollment as they had remained in school. The corresponding percentage for the preceding fiscal year was 48.

Student activities are summarized more thoroughly in the annual report on Section and Branch activities in the June issue of ELECTRICAL ENGINEERING, pages 268–71.

TECHNICAL PROGRAM COMMITTEE

Convention Programs. The technical program at the 1939 winter convention was more extensive and diversified than at any previous Institute convention. There was a total of 24 sessions—17 technical sessions, at which 77 technical papers were presented and discussed, 5 technical conferences, and 2 general sessions. This exceptional program met with a correspondingly exceptional response from the membership, as is indicated by the fact that registration at the convention was greater than at any convention since 1924. The unusually large technical program did not, by any means, exhaust the committee's fund of papers. After the formation of the winter convention program, there still remained on hand 25 high-grade papers which were held over for use at subsequent meetings.

In addition to the winter convention, the committee arranged programs for the 1938 summer and Pacific Coast conventions, and assisted in the provision of programs for district meetings at Lenox, Mass.; Miami, Florida; and Houston, Texas. A total of 184 papers were presented at these meetings, of which 169 were recommended by the committee for inclusion in TRANSACTIONS.

Technical conferences continue to be an important feature of the technical programs. A total of 12 were held during the year.

The registration at national conventions and District meetings showed an increase of about 15 per cent as compared with the previous year. This is attributable to some extent to the fact that there was one more District meeting than in the previous year. A very great increase in the attendance at the Pacific Coast convention (over 70 per cent) and a 12 per cent increase in the attendance at the winter convention was experienced. Data on attendance and other statistics are shown in table II.

Advance Copies of Technical Papers. Beginning with the 1938 summer convention in Washington, last year was the first year during which the new procedure relative to the provision of advance copies of technical papers was completely in force. The year's experience has proved the value of this procedure. This is indicated by the fact that a total of 61,000 preprints have been distributed during the past year, an average of 330 copies per technical paper. From the standpoint of authors, the new procedure is advantageous since it shortens from 90 to 60 days the minimum interval between the time when a paper is submitted to the Institute and the time when it may be presented. This latter advantage has been made effective through the adoption during the year of a revision of Section 93 of the bylaws as recommended by the committee.

This year, under the new procedure, preprints have been made available not only of all technical papers presented at national conventions but also of all papers presented at District meetings. This feature has been much prized by the District committees, and it is recommended that it be continued in so far as budget conditions permit.

General Sessions. In accordance with the general policy recommended by the committee and approved by the board of directors in 1937, "sessions at which subjects of general interest to all members are discussed" were arranged by the committee for the 1938 summer convention and the 1939 winter convention. At the 1938 summer convention, addresses were given by Dr. W. R. Gregg, Chief of the U.S. Weather Bureau, and Colonel J. M. Johnson, Assistant Secretary of the Department of Commerce, who spoke on weather forecasting, and aviation, respectively.

At the 1939 winter convention, the committee arranged for an address by Dr. Virgil Jordan on "Enterprise and Social Progress," and for a series of addresses constituting a symposium on the hurricane of September 1938. The speakers at the latter session were Mr. Walter Wesselius, of the American Red Cross, and Messrs. Sidney Withington, E. W. Doebler, C. W. Brown, T. H. Haines, and W. H. Harrison, who among them represented the power, railroad, and communication utilities, and who related the experiences of these utilities as a result of the hurricane. These general sessions have been very popular, attractive, interesting, and valuable additions to convention programs.

Manual of the Technical Program Committee. The committee has in preparation a revised manual of the practices and regulations which govern its operations. It is expected that the manual will be completed and submitted for duplication before the expiration of the committee's term of office. The committee's objective is to include in the manual all the information ordinarily needed by members of the technical program committee, technical committees, and District meeting committees in connection with the planning, procurement, and consideration of material for and conduct of technical sessions and conferences at national conventions and District meetings of the Institute.

Acknowledgment. The effectiveness of the committee's work has been the result of the efforts and devotion of many people—of its members, of course, of the chairmen of the technical committees, of the members of the technical committees, and of other cooperating committees, of the Institute's staff, and in particular of its secretary, Mr. Rich.

Table IV. Number of Applications Received From Enrolled Students and From All Others

Year Ending	From Students	From All Others	Total
April 30, 1939	849	872	1,721
April 30, 1938	739	932	1,671
April 30, 1937	716	1,040	1,756
April 30, 1936	631	946	1,577
April 30, 1935	575	715	1,290

Table V. Number of Enrolled Students

April 30, 1939	5,242 (2,271)
April 30, 1938	5,037 (2,428)
April 30, 1937	4,503 (2,249)
April 30, 1936	4,049 (1,991)
April 30, 1935	3,806 (1,983)

Following the number of Students reported for April 30 of each year is indicated within parentheses the number of new applications received during that year; the difference between this number and the reported total, of course, reflects the number of renewals of Student enrollment for the corresponding period.

Table III. Membership Statistics for the Fiscal Year Ending April 30, 1939

	Honorary	Fellow	Member	Six-Year Associate	Associate	Total
Membership on April 30, 1938	9	710	4,316	5,736	5,307	16,078
Additions						
Transferred	1	33	136	376		
New members qualified		1	100	35	1,265	
Former members reinstated			8	22	11	
	10	744	4,560	6,169	6,583	18,066
Deductions						
Died	1	18	42	43	13	
Resigned		9	45	145	107	
Transferred		1	29	127	389	
Dropped		1	52	187	259	
Membership on April 30, 1939	9	722	4,392	5,667	5,815	16,605

Publication Committee

The principal activity of the publication committee during the year has been the effort to bring to full fruition the improved publication service to our members made possible by the publication policy approved by the board of directors in the fall of 1937.

As a result of the change in policy, many changes in publication procedure were necessary, and, because it was quite impossible to make all of the changes simultaneously, ELECTRICAL ENGINEERING and the TRANSACTIONS for the year 1938 are, to some extent, non-uniform, part reflecting the old policy and part the new.

Starting with the September 1938 issue, ELECTRICAL ENGINEERING assumed its present standard form. The final change was a shift from a two-column to a three-column format for the technical program papers and discussions. Some had found the reading of the discussions somewhat difficult because of the small type size. Considering ease of reading, it is well established that there is a definite relation between the type size and column width, a wider column requiring a somewhat larger size of type. In this case, the column width was reduced, which gave the desired improvement in readability without incurring the additional expense that would have been involved in enlarging the size of type used for discussions. In fact, a small saving was made by using a slightly smaller size of type for the body of the technical program papers, the combined effect of the new type size and the narrower column being to increase the ease of reading here also. A special effort was made to get the reaction of the members to this change in typography, and, almost without exception, the responses were very favorable.

Special attention has been given to developing the general interest section of ELECTRICAL ENGINEERING, and here again, with very few exceptions, the comments of members have been favorable. The very few cases of adverse criticism of our publications under the new publication policy have been due in almost every instance to a lack of understanding of all of the provisions of the publication policy. To take care of this situation, plans are under way to include a full statement of the publication policy in the pamphlet "Suggestions to Authors," which is regularly issued by the Institute. It is probable that this more comprehensive pamphlet will be available by late summer or early fall.

The Institute has not published a cumulative index of the TRANSACTIONS since 1921, and there have been numerous requests for such an index. During the year, the publication committee sent a questionnaire to the membership to determine the amount of interest in a 17-year cumulative index to cover the years 1921–38, inclusive. The publication committee is happy to report that the response to the questionnaire was such as to indicate that the 17-year cumulative index could be made available on a practically self-supporting basis. As a result, the board of directors, at its January 1939 meeting, approved the publication of the index, and copies are now available.

The same questionnaire made inquiry as to the interest of the membership in a TRANSACTIONS supplement, which would include all of those technical program papers for the year 1938 which did not appear in ELECTRICAL ENGINEERING. The response to this inquiry was also favorable, with the result that those members who do not wish to purchase the bound volume of TRANSACTIONS may obtain the TRANSACTIONS supplement at a price of $0.50, and this supplement, together with the 12 issues of ELECTRICAL ENGINEERING, will give them a complete file of the technical program papers for the year.

The publication committee wishes to thank the membership for its splendid co-operation in the work of making effective the changes called for by the new publication policy. This co-operation has made the task of the publication committee a great deal lighter than it otherwise would have been.

Table VI. Number of Members in Section Territory Reinstated

August 1, 1938 to April 30, 1939	293
Year Beginning August 1, 1937	325
Year Beginning August 1, 1936	503
Year Beginning August 1, 1935	663
Year Beginning August 1, 1934	831

Table VII. Membership of the Institute, April 30, 1939

Of the 16,605 members reported for April 30, 1939, 14,371 are fully paid to April 30, 1939. The balance of 2,234 are divided into the following groups:

1. Members owing dues to April 30, 1938
   Total number of members who have not acted upon resolution of board of directors adopted in January 1939 providing an extension of time for payment of these dues 666
2. Members owing dues to April 30, 1939 1,568

(During the period May 1 to 20, 1939, 397 members have paid dues to April 30, 1939, reducing the total to 1,171.)

Membership Committee

The membership committee has put forth special effort this year to overcome the effects of current economic conditions on new membership results. Current business conditions are reflected in the reduction in applications received in 1937–38, and by a reduction in the percentage of members whose dues are fully paid as of April 30, 1939, as will be noted in tables IV and VIII.

The Section committees were organized early this year and were given complete written instructions regarding their work, together with the needed literature, to avoid any delay in getting started. Contacts with the students eligible for Associate grade were organized carefully to assure that each man would be reminded on several occasions of the importance of early affiliation with the Institute. The aid of the Branch counselors was enlisted in these contacts. Their response was splendid, and their efforts did much to assist this phase of the work.

The national committee was organized as last year with 21 members, 9 of whom were new additions. An organization meeting was held in September 1938, and another meeting was called during the winter convention, in January 1939, to review the progress made to date and to plan the work for the remainder of the year. No important changes have been made in the method of conducting the committee's work.

The Section membership committees have co-operated with the committee on transfers in encouraging eligible members to transfer to their proper grade of membership.

Table IV shows the large increase of applications received from enrolled students, which is due both to the increased activity already mentioned and to about 7½ per cent more prospects being available as compared with last year. The reduction in applications received "From All Others" is due largely to reduced returns from the Northeastern industrial section of the country. The total applications received is above last year's record by 50, but is 35 under the number received in 1936–37.

The total Institute membership has increased to 16,605, as compared with 16,078 on April 30, 1938—see table III.

The committee is pleased to see another healthy increase in the number of enrolled students—table V—since these men form the best source for future Associates.

Table VI shows a relatively small change in the number of delinquents reinstated

Table VIII. Memberships Fully Paid

	Membership as of April 30	Number of Members Fully Paid as of April 30	Per Cent Fully Paid
1939	16,605	14,371	86.5
1938	16,078	14,127	87.9
1937	15,308	13,439	87.8
1936	14,600	12,446	85.2
1935	14,269	11,512	80.7
1927 (year of maximum membership)	18,344	16,247	88.6

Table IX. Record of AIEE Membership

Year	Total Membership May 1	Year	Total Membership May 1	Year	Total Membership May 1
1884	71	1904	3,027	1923	15,298
1885	209	1905	3,460	1924	16,435
1886	250	1906	3,870	1925	17,319
1887	314	1907	4,521	1926	18,158
1889	333	1908	5,674	1927	18,344
1890	427	1909	6,400	1928	18,265
1891	541	1910	6,681	1929	18,133
1892	615	1911	7,117	1930	18,003
1893	673	1912	7,459	1931	18,334
1894	800	1913	7,654	1932	17,550
1895	944	1914	7,876	1933	17,019
1896	1,035	1915	8,054	1934	15,200
1897	1,073	1916	8,202	1935	14,269
1898	1,098	1917	8,710	1936	14,600
1899	1,133	1918	9,282	1937	15,308
1900	1,183	1919	10,352	1938	16,078
1901	1,260	1920	11,345	1939	16,605
1902	1,549	1921	13,215		
1903	2,229	1922	14,263		

comparison with the annual reductions of the past few years. The top figure of 293 is for nine months only and compares closely with 306 for the same period one year ago. The figures in this table may be expected to change little, or even to increase if business conditions cause an increasing number to become delinquent.

Table VII indicates again, as does table VIII, that there is a tendency on the part of a larger number to let dues payments wait. Last year, only 470 had not accepted the offer passed by the board of directors in January 1938, and 1,481 owed dues to April 30, 1938 (this latter number had been reduced to 1,211 by May 17, 1938). This condition should improve when world and business conditions become more stable.

Deaths

The deaths of 117 members reported during the year are listed in table X.

Committee on Transfers

Since the last report, the membership has voted amendments to the constitution, Section 4 of Article II and Section 10 of Article III, providing that application for transfer to grade of Fellow shall result only from proposal, and that at least five years of Member grade shall be a requirement; this with certain exceptions. These provisions, published in ELECTRICAL ENGINEERING, July 1938, pages 303–04, became effective July 21, 1938.

Material relative to Section transfer committee activity has been regularly circulated to all Section chairmen.

In order to ascertain the status of transfer committees in the Sections, questionnaire letters were sent to the Section chairmen. These were returned with results as follows:

58 Sections reported.

Of these, 19 have Section transfer committees, 16 receiving aid from the Section membership committee.

37 have no Section transfer committee. Of these, 33 Sections look to the Section membership committee for transfer responsibility. Twelve of these are discussing the matter or planning on having Section transfer committees.

The results of this survey would indicate that either through the Section transfer committee or the Section membership committee, as seems best to the Section executive committee, the coverage of transfer activities in the Sections is quite complete, needing only stimulation for increased performance.

The number of applications for transfer since 1927 is shown in table XI.

Board of Examiners

The board of examiners held 11 meetings during the past year, averaging about two and one-half hours each, and considered 3,820 cases, divided as shown in table XII.

Standards Committee

The increasing interest and activity of the various technical committees of the Institute in standardization which was reported during the previous year has been mani-

Table X. Deaths of AIEE Members Reported During the Fiscal Year

Name	Date of Election	Date of Death	Grade at Death	Obituary Notice in ELECTRICAL ENGINEERING
Aanonsen, Hans E.	Associate '07		Associate	Jan. 1939, p. 53
Abell, Harry C.	Associate '03	Nov. 24, 1938	Associate	Jan. 1939, p. 53
Ahearn, Thomas	Associate '87	June 28, 1938	Member	Aug. 1938, p. 363
Alderman, Haywood L.	Associate '27	Jan. 11, 1939	Member	Feb. 1939, p. 93
Alexander, James F.	Member '21	Oct. 8, 1938	Member	Dec. 1938, p. 523
Battern, Algy R.	Associate '20		Associate	Aug. 1938, p. 364
Benham, Claude F.	Associate '16	Sept. 12, 1938	Member	Nov. 1938, p. 473
Bird, Montgomery R.	Associate '36	Nov. 27, 1936	Associate	Dec. 1938, p. 524
Blondel, Andre E.	Associate '05	Nov. 15, 1938	Honorary Member	Feb. 1939, p. 93
Bracken, James L. F.	Associate '18	Oct. 21, 1938	Associate	Dec. 1938, p. 523
Brandenburger, Leo	Associate '37	Feb. 11, 1938	Associate	Oct. 1938, p. 436
Bronson, Frederick M.	Member '36	Oct. 13, 1938	Member	Dec. 1938, p. 523
Brown, Glendon C.	Member '37	1938	Member	March 1939, p. 141
Brubaker, Charles N.	Associate '19	May 3, 1938	Member	Aug. 1938, p. 364
Buck, Nelson E.	Associate '19	Dec. 12, 1938	Associate	March 1939, p. 141
Burt, Austin	Associate '07	Sept. 1938	Fellow	April 1939, p. 186
Cammack, John E.	Associate '19	March 1939	Associate	May 1939, p. 229
Carpenter, Dan E.	Member '15	Sept. 7, 1938	Member	Oct. 1938, p. 436
Clothier, Henry W.	Member '17	March 11, 1938	Member	June 1938, p. 275
Coates, Charles B.	Associate '03	March 17, 1939	Member	May 1939, p. 229
Collings, Llewellyn W.	Associate '37	Dec. 27, 1938	Associate	Feb. 1939, p. 93
Connolly, Stephen J.	Associate '08	Jan. 29, 1938	Associate	July 1938, p. 325
Crates, Royal R.	Associate '37	March 10, 1939	Associate	May 1939, p. 229
Cunningham, Andrew J.	Associate '35	Dec. 1937	Member	Aug. 1938, p. 364
Dalton, William J.	Associate '24	July 9, 1938	Associate	Sept. 1938, p. 395
Davis, Albert G.	Associate '98	April 25, 1939	Fellow	June 1939, p. 279
Dawson, William F.	Associate '05	Jan. 19, 1939	Fellow	March 1939, p. 141
Deck, Frederick W.	Member '30	Sept. 26, 1938	Member	Nov. 1938, p. 473
Denmann, Burt J.	Associate '11	June 25, 1938	Associate	Aug. 1938, p. 364
Dick, William A.	Associate '02	Dec. 5, 1938	Fellow	May 1939, p. 229
Dickerson, E. N.	Associate '84		Associate	
Dodd, Maynard	Member '24	April 10, 1938	Member	June 1938, p. 275
Doty, Paul	Associate '04	Dec. 3, 1938	Associate	March 1939, p. 140
Ducey, Walter J.	Associate '22	Sept. 29, 1938	Member	Nov. 1938, p. 473
Ellis, Joseph	Associate '17	Oct. 2, 1938	Associate	Jan. 1939, p. 54
Frederiksen, Victor	Associate '32	April 23, 1938	Associate	Oct. 1938, p. 436
Freidenmann, John W.	Member '30	Feb. 13, 1938	Member	June 1938, p. 274
Furiess, Douglas L.	Associate '18	June 19, 1938	Associate	Sept. 1938, p. 395
Gallagher, Francis W.	Associate '37	Sept. 18, 1938	Associate	Jan. 1939, p. 54
Gallatin, Albert R.	Associate '98	March 1939	Associate	June 1939, p. 281
Gillespie, Leigh R.	Associate '19	Nov. 1938	Member	Jan. 1939, p. 53
Geisler, Hugo P., Jr.	Member '36	Sept. 10, 1938	Member	Dec. 1938, p. 523
Glaubitz, Hugh J.	Member '17	Jan. 14, 1939	Member	March 1939, p. 140
Green, Richard	Associate '34	March 29, 1938	Associate	July 1938, p. 326
Guttmann, Raymond	Associate '35	Feb. 22, 1938	Associate	Dec. 1938, p. 524
Hardy, Carl E.	Associate '99	Feb. 15, 1939	Associate	April 1939, p. 186
Harris, Charles H.	Associate '34	Oct. 22, 1938	Associate	Dec. 1938, p. 523
Hawkins, Charles C.	Associate '03	Aug. 1938	Associate	Nov. 1938, p. 473
Hayes, Timothy A. J.	Associate '32	April 14, 1938	Associate	June 1938, p. 275
Henning, Clarence I. B.	Associate '13	Jan. 26, 1939	Associate	March 1939, p. 141
Hermann, Henry	Associate '15	Oct. 17, 1938	Associate	April 1939, p. 186
Hirshfeld, Clarence F.	Associate '05	April 19, 1939	Fellow	May 1939, p. 229
Hopewell, Charles F.	Associate '97	Oct. 17, 1938	Member	March 1939, p. 141
Hoppe, Walter H.	Associate '30	Nov. 1938	Associate	Jan. 1939, p. 54
Horne, Leslie H.	Associate '10	Dec. 6, 1938	Associate	Feb. 1939, p. 94
Huseby, Gisle E.	Associate '26	Oct. 2, 1938	Associate	Dec. 1938, p. 524
Hussey, Abram	Associate '06	Aug. 17, 1937	Member	Oct. 1937, p. 1334
Hutchinson, Cary T.	Associate '90	Jan. 16, 1939	Fellow	March 1939, p. 140
Insull, Frederick W.	Member '37	Jan. 14, 1939	Member	March 1939, p. 141
Insull, Samuel	Associate '86	July 15, 1938	Fellow	Aug. 1938, p. 363
Jackson, Ray P.	Associate '06	Nov. 1937	Associate	July 1938, p. 326
Jacoby, S. Clifford	Associate '21	Oct. 20, 1938	Member	Dec. 1938, p. 523
Jennison, Herbert C.	Associate '05	June 12, 1938	Associate	Oct. 1938, p. 437
Jorgensen, Lars R.	Associate '05	May 8, 1938	Member	July 1938, p. 326
Keyes, Clift B.	Associate '03	Dec. 7, 1938	Member	Jan. 1939, p. 53
Kiligore, Lloyd M.	Associate '18	March 1938	Associate	Jan. 1939, p. 54
Knaur, Richard J.	Associate '22	April 26, 1938	Associate	Aug. 1938, p. 364
Lackie, Walter J.	Associate '28	May 26, 1938	Associate	Sept. 1938, p. 395
Lanphier, Robert C.	Associate '01	Jan. 28, 1939	Fellow	March 1939, p. 141
Lawton, Arthur H.	Associate '03	Dec. 2, 1938	Fellow	Jan. 1939, p. 53
Maxwell, Eugene	Associate '06	July 28, 1938	Associate	Nov. 1938, p. 473
McQuarrie, James L.	Associate '07	March 1, 1939	Fellow	April 1939, p. 186
Meredith, Gailen E.	Associate '19	April 20, 1938	Member	July 1938, p. 326
Miller, Charles A.	Associate '21	Aug. 23, 1938	Associate	Oct. 1938, p. 437
Mintzner, Watkins F.	Associate '20	Aug. 22, 1938	Associate	Dec. 1938, p. 523
Moody, Walter S.	Associate '06	Nov. 7, 1938	Fellow	Dec. 1938, p. 523
Mordey, William M.	Associate '91	July 1, 1938	Associate	Sept. 1938, p. 395
Morgan, Oliver J.	Associate '36		Associate	April 1939, p. 186
Munshi, Dinshaw P.	Associate '32	Dec. 16, 1937	Associate	Aug. 1938, p. 364
Nagel, William G.	Associate '03	July 20, 1938	Associate	Oct. 1938, p. 437
Packer, Edson F., Jr.	Associate '36	June 13, 1938	Associate	Aug. 1938, p. 364
Panter, Thomas A.	Associate '03	March 12, 1939	Fellow	May 1939, p. 229
Parry, Evan	Associate '95	Dec. 17, 1938	Associate	Feb. 1939, p. 93
Peck, Emerson P.	Associate '08	Nov. 14, 1938	Fellow	June 1939, p. 280
Pike, Clayton W.	Associate '91	Dec. 30, 1938	Member	April 1939, p. 186
Ratcliff, Henry A.	Member '22	April 26, 1938	Member	June 1938, p. 275
Reid, Edwin S.	Associate '96	July 20, 1938	Member	Nov. 1938, p. 473
Robbins, Percy A.	Associate '03	April 23, 1938	Associate	July 1938, p. 325
Roberts, Samuel N.	Associate '21	Jan. 1939	Associate	March 1939, p. 141
Robertson, James T.	Associate '06	Sept. 6, 1938	Member	Nov. 1938, p. 473
Roller, Frank W.	Associate '95	Aug. 21, 1938	Fellow	Sept. 1938, p. 395
Ross, James D.	Associate '08	March 14, 1939	Fellow	April 1939, p. 185
Ruffner, Charles S.	Associate '02	Jan. 21, 1939	Fellow	March 1939, p. 140

Table X (Continued). Deaths of AIEE Members Reported During the Fiscal Year

Name	Date of Election	Date of Death	Grade at Death	Obituary Notice in ELECTRICAL ENGINEERING
Ryan, William T.	Associate '07	Feb. 5, 1939	Member	March 1939, p. 140
Seletzky, Anatoli C.	Associate '29	May 11, 1938	Member	June 1938, p. 274
Shearer, Harold H.	Member '20	Nov. 10, 1938	Member	Dec. 1938, p. 523
Shute, Loren H.	Associate '15	Feb. 10, 1939	Associate	June 1939, p. 280
Snell, Sir John F. C.	Associate '06	July 6, 1938	Fellow	Aug. 1938, p. 363
Sterba, Ernest J.	Associate '21	April 24, 1939	Member	June 1939, p. 280
Strasburger, Edgar	Associate '03		Associate	May 1939, p. 229
Sutherland, Wm. J. K.	Associate '15	March, 1938	Associate	Oct. 1938, p. 436
Swallow, Joseph G.	Associate '09	Jan. 14, 1939	Associate	April 1939, p. 186
Terry, Charles A.	Associate '87	Feb. 18, 1939	Member	April 1939, p. 186
Thompson, John H.	Associate '21	Oct. 31, 1938	Associate	Jan. 1939, p. 54
Thornton, Kenneth B.	Associate '01	Feb. 10, 1938	Member	Dec. 1938, p. 523
Thrush, George H., Jr.	Associate '34	Sept. 25, 1938	Associate	Dec. 1938, p. 523
Uhlenhaut, Fritz, Jr.	Associate '89	Jan. 1, 1937	Member	Feb. 1939, p. 94
Upley, Arnold S.	Associate '37		Associate	Dec. 1938, p. 524
Walker, Earle T.	Associate '35	Sept. 22, 1937	Associate	July 1938, p. 326
Warner, John C.	Member '34	July 21, 1938	Member	Sept. 1938, p. 395
Watson, Malcolm V.	Associate '07	April 25, 1938	Member	June 1938, p. 274
Weeks, Edwin R.	Associate '87	Aug. 17, 1938	Fellow	Oct. 1938, p. 436
Whitmore, Walter G.	Associate '90	Nov. 30, 1938	Associate	Feb. 1939, p. 94
Wilbraham, F. M.	Associate '19	Jan. 21, 1939	Associate	April 1939, p. 186
Wilcox, Herbert M.	Member '37	July 28, 1938	Member	Sept. 1938, p. 395
Wittenberg, Michael	Member '24	Jan. 1930	Member	March 1939, p. 141
Young, Walter E.	Associate '19	June 22, 1938	Member	Sept. 1938, p. 395

fested during the present year. There was also increased participation by the Institute in ASA projects through the appointment of representatives on a number of new sectional committees. Of particular interest is the work started in the ASA on lightning arresters, storage batteries, and on a test code for fractional horsepower motors initiated by a subcommittee of the AIEE committee on electrical machinery. A reorganization of the sectional committee on electric welding is now under way. The Institute has also appointed representatives on a sectional committee that will attempt to develop international marine standards as affecting electrical installations on shipboard.

During the year, important new AIEE standards have been issued and others revised as follows: Notably, the completely revised edition of the Marine Rules, a new test code on apparatus noise measurement and standards for oil circuit breakers and indicating instruments.

In accordance with plans made during the previous year, three regular sessions and two symposiums at the winter convention were devoted to discussion of standards for the rating of various types of electrical machinery, especially motors and transformers. A total of 12 formal papers were presented. The sessions were very well attended and a great deal of interest was displayed by the membership at large, indicating that future meetings of similar character will be justified. Several papers relating to standards activities are contemplated for inclusion in the program for the summer convention.

The standards committee, realizing that a certain amount of co-ordination of standardization work carried on by the technical committees is desirable, and also that the Institute might carry on to good advantage some standards activities not ordinarily falling within the scope of the existing technical committees, has organized a number of co-ordinating committees for the following purposes:

(a). To compile data on existing conditions and standards which will assist in determining the need for better co-ordination.

(b). To prepare guiding principles to be used by the other AIEE committees in their standards work.

(c). To maintain contact with all interested AIEE committees and also with national and international standardization agencies outside of the Institute.

(d). To recommend, initiate, or sponsor setups in the ASA, IEC, and other standardization bodies which seem desirable or expedient for bringing about maximum co-ordination of standards in the electrical field.

(e). To initiate, in co-operation with interested AIEE technical committees, regular or informal Institute sessions for the purpose of discussing vital issues of standardization.

At present these committees cover the following subjects: Reference Values for Standards, Standard Voltages and Currents, Insulation Testing and Co-ordination, and Basic Principles for Rating of Electrical Machines and Apparatus. The last-named committee will first work on a revision of AIEE standard No. 1, General Principles Upon Which Temperature Limits Are Based in the Rating of Electrical Machinery and Apparatus, utilizing in part information and data contributed in papers and symposiums during the winter and summer conventions.

Table XI. Applications for Transfer

Year Ending April 30	Fellow Grade: Recommended	Fellow Grade: Not Recommended	Fellow Grade: Total	Member Grade: Recommended	Member Grade: Not Recommended	Member Grade: Total
1927	30	5	35	293	32	325
1928	21	3	24	280	17	297
1929	45	2	47	229	19	248
1930	28	2	30	211	29	240
1931	44	3	47	322	31	353
1932	7	2	9	149	17	166
1933	29	2	31	109	11	120
1934	25	2	27	154	3	157
1935	19	2	21	199	23	222
1936	27	1	28	205	24	229
1937	24	2	26	167	27	194
1938	26	0	26	137	7	144
1939	25	2	27	126	13	139
Totals	350	28	378	2,581	253	2,834

As a further means for increasing the interest of the membership in the standardization activities of the Institute, it has been decided to augment the columns of ELECTRICAL ENGINEERING where brief reports on standards activities are given.

A plenary meeting of the International Electrotechnical Commission was held in Torquay, England, during the past year, at which 25 or more committees participated. A number of members of the Institute interested in standardization attended this meeting.

UNITED STATES NATIONAL COMMITTEE OF THE IEC

Nineteen-thirty-nine was an active year for the International Electrotechnical Commission. A very successful plenary meeting was held at Torquay, England, June 22 to July 1, this being the ninth plenary meeting. It was attended by 400 delegates from 22 countries, the United States being represented by 22 delegates.

Many important final decisions, as recorded in the brief reports below, were taken. Of outstanding importance was the recommendation of advisory committee 24 that the permeability of free space be the connecting link between the electrical and mechanical units of the Giorgi (MKS) System.

At the closing dinner to the delegates given by the British Standards Institution at the Guildhall, London, the Duke of Kent said:

The International Electrotechnical Commission's work in co-ordinating and simplifying industrial requirements in the electrical field should prove of the highest value to international exchange of electrical goods. This co-ordination should be increasingly valuable as the economic interdependence of the nations is more fully recognized.

A brief summary of some of the actions taken at the Torquay meeting is given below:

International Electrotechnical Vocabulary, IEC. 1. The first edition of the vocabulary, containing some 2,000 scientific and technical terms defined in both French and English, and with the titles in German, Spanish, Italian, and Esperanto, was approved for publication. About 150 copies have been distributed in this country.

Table XII. Applications for Admission and Transfer

Applications for Admission		
Recommended for grade of Associate	1,330	
Re-elected to the grade of Associate	86	
Not recommended	10	1,426
Recommended for grade of Member	95	
Re-elected to the grade of Member	11	
Not recommended	43	149
Recommended for grade of Fellow	1	
Re-elected to the grade of Fellow	—	
Not recommended	1	2
Applications for Transfer		
Recommended for grade of Member	126	
Not recommended	13	139
Recommended for grade of Fellow	25	
Not recommended	2	27
Students		
Recommended for enrollment as Students		2,079
Total		3,820

Transformers, IEC 2B. Two divergent methods of rating transformers have been in general use in different countries, one based on the full-load secondary current and the no-load secondary voltage, and the other based on the full-load secondary current and the full-load secondary voltage at a specified power factor (0.8 or 0.85). The IEC meeting at Torquay agreed that both the IEC test rating and the IEC service rating should be shown on the nameplate. It was also agreed that when no power factor is specified by the purchaser the service rating will be based on a power factor of 0.8, and that losses should be expressed in kilowatts and not as a percentage efficiency. Fractional loads are to be expressed in terms of current. The test rating agreed upon by the IEC as one of the factors to be used in rating transformers defines a transformer in which it might be desired to reverse the direction of flow of power, and the service rating defines a transformer with a predetermined direction of flow.

It was agreed that ambient temperature should be defined to mean that the peak value of 40 degrees centigrade should be associated with an average temperature not exceeding 35 degrees centigrade over any 24-hour period. The maximum temperature rise for oil-immersed transformers, with forced oil circulation, it was agreed, should be 65 degrees centigrade.

Graphical Symbols, IEC 3. IEC Publication 42, graphical symbols for heavy current systems, will be revised on the basis of decisions taken at Torquay. Publication 42, graphical symbols for weak current systems, will be submitted to the national committees for approval of the revision agreed to at Torquay.

Steam Turbines, IEC 5. Two IEC publications (45 and 46) were extended to cover all other kinds of turbines not heretofore covered. Certain decisions were also taken on fluid flow measurement.

Lamp Caps and Holders, IEC 6. Dimensions of lamp caps and holders, approved by this committee, will be published by the IEC. Drawings of gages were approved, but each National Committee will, of course, decide for itself what gages would be used for checking the dimensions.

Aluminum, IEC 7. It was unanimously agreed that annealed aluminum should be defined as aluminum which, in the form of wire of 1 mm diameter and greater, has a maximum tensile strength of 9.5 kg per square mm and a minimum elongation of 20 per cent in a length of 200 mm. The measurement of the elongation is to be taken after fracture. The normal resistivity value should be 0.0278 ohm mm^2/m at a temperature of 20 degrees centigrade. The temperature coefficient and density for hard-drawn aluminum are considered the same as for annealed aluminum. For the steel core it was agreed to adopt a minimum tensile strength of 120 kg/mm^2 and an elongation of 5 per cent for wires of 3 mm diameter and over, and 4 per cent for wires which are smaller than 3 mm diameter. Standards of resistivity for aluminum used for insulated cables and bus bars were agreed upon.

Standard Voltages and High Voltage Insulators, IEC 8. A column showing the three-phase phase-voltages corresponding to the three-phase phase-to-neutral voltages will be included in the new edition of the IEC publication on Standard Voltages, in the section on voltage between 100 and 1,000 volts. The first edition of an international specification on the testing of insulators will be issued, it was agreed. Impulse voltage tests for the testing of line insulators will be included.

The meeting referred a draft specification for testing wall bushing insulators to the national committees for consideration, and approved a report recommending the revision of the IEC calibration tables for sphere gaps.

Electric Traction Equipment, IEC 9. A revised edition of the specification for traction motors will be circulated to the national committees for approval.

Overhead Lines, IEC 11. A new edition, in French, of Publication No. 49, comparison of the regulations in force in various countries for the erection of overhead lines, has been prepared. Further consideration will be given to formulas proposed for the calculation of the loading of overhead lines.

Electrical Instruments, IEC 13. Revision of the publications on alternating current watt-hour meters; instrument transformers; and indicating instruments was discussed, and action will be taken later. This committee held a joint meeting with the advisory committee on terminal markings, and the two committees appointed a subcommittee to consider marking instrument transformers separately from instruments and meters.

Terminal Markings, IEC 16. A report by this committee summarized the systems of terminal markings now in use as follows:

(a). The system used in the United States as given in the American Standard for rotation, connections, and terminal markings for electric power apparatus.

(b). The system used in Great Britain which will be available soon as a report of the British Standards Institution.

(c). A composite system taking certain of its parts from the systems of the different nations on the continent of Europe, the composite being arrived at in discussions in IEC Advisory Committee Number 16.

It is expected that the IEC will print the composite system as a report in the hope that as the various nations find it necessary to change their existing systems they will be able to adopt this system in whole or in part.

The IEC will also publish a separate report giving the history of the whole situation on terminal markings, explaining the three separate systems and giving information as to where detailed information on all of them may be obtained.

Switchgear, IEC 17. Insulation tests, impulse voltage tests, the natural frequency of the test circuit and the rate-of-rise of recovery voltage and the testing of large circuit breakers were discussed.

Electric Cables, IEC 20. A revision of the IEC specifications was suggested and proposed changes were submitted to a subcommittee for consideration.

Electric and Magnetic Magnitudes and Units, IEC 24. It was agreed that the committee recommend that the connecting link between the electrical and mechanical units in the MKS system should be the permeability of free space (μ_0) with the value of 10^{-7} in the unrationalized system, $4\Pi 10^{-7}$ in the rationalized system. The committee also agreed to recommend that the name of the unit of force should be the "Newton."

Letter Symbols, IEC 25. A revised edition of IEC publication 27 will be circulated to the national committees for approval.

Electric Welding, IEC 26. The first meeting of this committee decided that it will start its program with work on welding plant and equipment, and that it will co-operate with the committee on welding of the International Standards Association. Definitions, rating of welding plant and equipment, non-automatic single-arc direct-current welding sets, automatic single-arc direct-current welding sets, constant-voltage multiple-arc direct-current welding sets, electric motors, air-cooled direct-current reactors, and chokes and transformers were discussed. Proposals made by the British committee will be reviewed and referred to the various national committees for their recommendations.

More detailed reports of all committee meetings are available. Anyone interested should write to J. W. McNair, secretary of the U.S. national committee of the International Electrotechnical Commission, American Standards Association, 29 West 39th Street, New York.

It is now expected that meetings of the following IEC advisory committees will be held in New York, September 5–8, 1939.

2b Transformers
4 Hydraulic Turbines
17 Switchgear
19 Internal Combustion Engines
26 Welding

The organization meeting of the new committee on insulation co-ordination and possibly the subcommittee on sphere gaps.

Committee on Planning and Co-ordination

The recommendation of the predecessor, the committee on co-ordination of Institute activities, that the committee be reconstituted under the title "committee on planning and co-ordination" and assume the broader duties thus indicated was approved by the board of directors, with the change effective August 1, 1938. Section 70 of the bylaws was amended to assign to the committee the additional duty of giving continuous attention to the planning of Institute activities of the future.

The committee invited a considerable group of members to supply their views on the present activities of the Institute and their suggestions regarding any changes or additions which would make the organization more valuable to the profession in general and its members in particular.

A comprehensive report on present and proposed future activities of the Institute, based very largely on the 29 replies received and the views of members of the committee, has been submitted for consideration of the board of directors at its May meeting.

In accordance with past practice, the committee received requests from District and Section officers for national conventions and District meetings desired in their Districts in 1940, and submitted a recommended schedule of such meetings, which was approved by the board of directors in January.

Institute Policy Committee

The only matter referred to the committee during the year was the question as to

whether the Institute should include in its scope of activity consideration of an engineering approach to the physical facts of depreciation and obsolescence of electrical material.

The AIEE executive committee requested the Institute policy committee to submit an outline of the principal factors, both for and against participation in this field, that should be considered by the board of directors.

Committee on Safety

By an action of the board of directors the functions of the committee on safety codes were expanded, and a committee on safety created to include the entire field of safety in electrical engineering.

The committee, in letters, has endeavored to interest universities, and in particular their electrical engineering departments, in the matter of accident prevention and including instruction in the proper method of resuscitation from electric shock, asphyxiation, drowning, et cetera. Suggestions have been included that other departments of the universities may also be interested in the subject, with emphasis on instruction to all students, particularly because of the frequent occurrence of such accidents outside of university laboratories. Such training among the electric and gas utility companies has, over the years, resulted in the saving of the lives of many persons who have accidentally come in contact with energized parts, or apparently have been drowned, or asphyxiated from gas fumes. The committee is convinced that continual training in this method is absolutely essential and that, to be most effective, such training should be given before students have left the universities. Letters were therefore sent to 120 professors of electrical engineering of the various universities and colleges, together with a booklet describing the Schafer Prone Pressure Method of Resuscitation. The replies were immediate and evidenced a highly co-operative spirit. Correspondence is continuing with such universities.

Letters were also sent by the committee to the counselors of student branches of the universities, requesting that during the year each student branch arrange to have presented before the branch a paper dealing with some phase of the problem of prevention of accidents or remedial measures after electrical shock. This had been discussed with the chairman of the committee on student branches and received his wholehearted endorsement. Assistance was offered, if necessary, to secure a local speaker to prepare and present such a paper. Again the reaction was spontaneous, and steps have been inaugurated to attain this during this or the coming year, where this subject had not already been included in the meetings.

A similar letter was authorized to be sent to the various Sections of the Institute to recommend to them that during each year they arrange to have presented before each Section a paper dealing with the prevention of accidents or remedial measures after electrical shock. It was found that, in general, arrangements were being made by the Sections to include this important subject in their programs.

There exists a great need for the distribution of a comprehensive booklet on resuscitation, of convenient size, which people could readily obtain for reference.

A movement has been started to obtain information relating to safety practices from all related foreign institutes of various kinds. Abstracts are being prepared of replies received, and it is hoped that a comprehensive summary of practices will be available soon.

The committee was successful early in the year in arranging for the preparation of a paper for a general meeting. The paper now under preparation is concerned with safe practices in college laboratories, dealing largely with methods to assure safety to the laboratory students and personnel. Arrangements have been made for the preliminary presentation of this paper at a meeting of the Society for the Promotion of Engineering Education.

During the year, a number of subjects relating to electrical safety were presented for discussion. It was found that such subjects being given active consideration were concerned with the developments in, or revision of, electrical codes or standards in general sponsored under the auspices of the American Standards Association. Some of the subjects, from a purely technical viewpoint, are being given further consideration.

The committee is of the opinion that the time to make apparatus safe for construction, operation, and maintenance is at the time that the apparatus is being designed. It has therefore recommended to the National Electrical Manufacturers Association that they request their members to add a line on the original drawings to provide that the design be checked for safety in the engineering department or drafting office. This recommendation might well be also carried out by manufacturers and public utilities generally.

Committee on Legislation Affecting the Engineering Profession

The committee on legislation affecting the engineering profession, consisting of fifteen members well representative of all of the Sections, has carried on its work along the lines similar to those of previous years.

Some thought has been given to possible methods which might enable the committee to keep in touch with proposed legislation regarding licensing of engineers that may be introduced in the various state legislatures so that the Institute could be promptly and properly informed regarding those developments with a view toward being helpful.

The Texas registration law was contested during the year in the courts, and, upon the request of the national secretary, all of the pertinent information available at the time in connection with the case was obtained from the secretary of the Texas State board and the dean of engineering of the University of Texas and forwarded to the Institute. The principal controversial point in this case hinged upon the definition of "principles of engineering" used in the Texas law, and upon final disposition of this matter a report will be made to the national secretary of the Institute.

Committee on Code of Principles of Professional Conduct

Members of this committee have each been provided with a copy of the codes of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Chemical Engineers, the American Institute of Consulting Engineers, and the American Association of Engineers in addition to our own code, and have considered whether our code required modification. No suggestions have come forth proposing modifications, and it therefore may be interpreted that none is necessary at the present time.

Committee on Constitution and Bylaws

This committee considered and recommended several proposed amendments to the bylaws of the Institute. The committee conducted its work by correspondence.

Committee on Economic Status of the Engineer

Members of the committee met informally at the winter convention. In the matters of employment, unemployment security, and annual income there are available the publication of bulletins No. R-497, 543, 588, and 631 by the United States Department of Labor covering the engineering profession, 1929–34, Professor Sorensen's paper on the Economic Status of the Engineer, Transactions, 1938, and a bulletin of the National Bureau of Economic Research, February 1939, comparing engineers' income with that of other professions. The committee feels, therefore, that adequate data on that phase of its assignment have been presented.

The committee is observing the progress of the ECPD committee on professional recognition, and has noted its recent study of the qualification procedure in the fields of accounting, architecture, law, and medicine. The committee is watching the policies and organization plans of other professional engineering societies and federations of engineers, and the trend of possible reorganization and revision of the objectives of the American Engineering Council.

Committee on Award of Institute Prizes

Three national and 12 District prizes were awarded in 1938 for papers presented in the calendar year 1937 and for student papers presented during the academic year ending June 30, 1938. These awards were announced in the issues of Electrical Engineering for July, September, and December 1938 and April 1939.

The committee considered a large number of papers and the gradings and recommendations of the technical committees which had reviewed the papers. Many papers considered were of a high quality, and, in addition to the national prizes, ten other papers were given honorable mention.

Committee on Award of Columbia University Scholarships

During February and March 1938, there were twelve applications for the Columbia University scholarship. After due consideration of the merits of all the applicants, the committee voted to award the scholarship for 1938–39 to Mr. James E. Hulsizer, who received his B.S. degree from Princeton in June 1938. Mr. Hulsizer accepted the

scholarship, and has been in regular attendance during the present academic year.

Edison Medal

The Edison Medal, which is awarded by a committee composed of 24 members of the Institute, was, for 1938, awarded to Dr. Dugald C. Jackson "for outstanding and inspiring leadership in engineering education and in the fields of generation and distribution of electric power," and was presented on January 25, 1939, during the winter convention. The medal may be awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

John Fritz Medal

The John Fritz Medal board of award, composed of representatives of the national societies of civil, mining, mechanical, and electrical engineers, awarded the 35th medal (for 1939) to Dr. Frank B. Jewett, vice-president, American Telephone & Telegraph Company, and president, Bell Telephone Laboratories, Inc., for "vision and leadership in science, and for notable achievement in the furtherance of industrial research and development in communication."

Lamme Medal

The Lamme Medal committee awarded the medal for 1938 to Marion A. Savage, designing engineer, General Electric Company, "for able and original work in the development and improvement of mechanical construction and the efficiency of large high speed turbine alternators." Arrangements are being made for the presentation of the medal at the combined Summer and Pacific Coast convention in San Francisco, Calif., June 26–30, 1939. The medal may be awarded annually to a member of the AIEE "who has shown meritorious achievement in the development of electrical apparatus or machinery."

Alfred Noble Prize

This prize, established in 1929, consists of a certificate and a cash award of $500 from the income from a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past-president of the American Society of Civil Engineers and of the Western Society of Engineers. It may be made to a member of any of the co-operating societies, ASCE, AIME, ASME, AIEE, or WSE, for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age. The award for 1938 was presented to Ralph J. Schilthuis for his paper on "Connate Water in Oil and Gas Sands."

Washington Award

The Washington Award for 1939 was bestowed upon Dr. Daniel Webster Mead, "for his superior contribution to sound theory, good practice, and high ethical standards in the creation of engineering works as an engineer and as a teacher," and was presented to him at a dinner on February 20, 1939. This award may be made annually to an engineer by the commission of award composed of nine representatives of the Western Society of Engineers and two each of the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and AIEE.

Hoover Medal

The Hoover Medal was established through a trust fund created by a gift from Conrad N. Lauer, and is to be awarded periodically "to a fellow engineer for distinguished public service" by a board representing the national societies of civil, mining and metallurgical, mechanical, and electrical engineers. The third recipient of this medal was John Frank Stevens, who was cited as an "engineer of great achievement, as illustrated in his work on the Panama Canal, who, in his dealings with the inter-allied forces in Siberia in the Great War, demonstrated those broader capacities for humanitarian public service beyond his calling."

Iwadare Foundation Committee

No Iwadare lecturer was chosen to go to Japan for the current year, nor has any Iwadare Fellow come to the United States.

Employment Service

The Institute co-operates with the national societies of civil, mining, and mechanical engineers in the operation of the Engineering Societies Employment Service with its main office in the Engineering Societies Building, New York. Offices are operated in Chicago and San Francisco also. In addition to the societies named, others co-operate in certain of the offices as follows: New York—Society of Naval Architects and Marine Engineers; Chicago—Western Society of Engineers; San Francisco—California Section of the American Chemical Society; and the Engineers' Club of San Francisco.

The service is supported by the joint contributions of the societies and their individual members who are benefited. In addition to the publication of the employment service announcements monthly in Electrical Engineering, weekly subscription bulletins are issued for those seeking positions.

An analysis of this employment service as reported to the national societies is given in table XIII.

Table XIII. Analysis of Employment Service

Month	Men Registered				Men Placed			
	New York	Chicago	San Francisco	Total	New York	Chicago	San Francisco	Total
1938								
May	258	135	106	499	34	18	23	75
June	289	169	97	555	55	12	7	74
July	188	98	86	372	28	20	33	81
August	181	86	80	347	47	33	28	108
September	199	99	50	348	50	23	21	94
October	175	67	79	321	57	23	26	106
November	133	58	51	242	45	30	13	88
December	102	46	79	227	37	13	17	67
1939								
January	144	37	73	254	53	16	23	92
February	143	62	85	290	40	16	12	68
March	169	67	109	345	51	19	19	89
April	140	96	91	327	46	21	16	83
Total	2,121	1,020	986	4,127	543	244	238	1,025

American Engineering Council

The American Engineering Council has continued to carry on a wide range of activities within the scope of its objectives: "to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions."

The 19th annual meeting of the assembly was held in Washington, D. C., January 12–14, 1939. The 9th conference of engineering society secretaries was held on the 12th.

During 1938, the Council sponsored two forums which were held with the co-operation of local organizations of engineers, the first in Philadelphia, May 13, on the subject "Employment and the Engineer's Relation to It," and the second in Detroit, November 11, on "Invention and the Engineer's Relation to It." On account of the success of these two meetings, the annual meeting was planned as a series of forums on the following subjects, suggested by the work of several of the Council's committees:

1. National Planning and the Engineer's Relation to It.
2. The Economic Status of the Engineering and Kindred Professions.
3. Engineering Aspects of Government Reorganization.
4. Engineering and Economic Factors in the Size of Business.

At the all-engineers dinner, Dr. Vannevar Bush, president of the Carnegie Institution of Washington, and a director of the AIEE, delivered an address on "The Qualities of a Profession," which was published in the April 1939 issue of Electrical Engineering, pages 156–60.

The business session was devoted to consideration of committee reports and other matters, as well as the financial status of the Council. It was reported that the National Industrial Conference Board had

recently granted $22,500 for the conduct of a special study under the direction of the Council's subcommittee on patents.

United Engineering Trustees, Inc.

This organization is the corporate body which holds title in the name of the four Founder Societies to their joint physical properties, namely, the Engineering Societies Building, the Engineering Societies Library, and the endowment funds of The Engineering Foundation. It operates and manages the Engineering Societies Building and administers certain joint activities of the four Founder Societies.

The annual report of the UET for the year which ended September 30, 1938, showed practically full occupancy of the building, gratifying use of meeting halls, and a stable financial situation.

An abstract of the report was published in Electrical Engineering for December 1938, pages 518–19.

Engineering Foundation

The Engineering Foundation is a joint organization of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers established for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind."

The Foundation's funds were augmented by a bequest from the late Ambrose Swasey of $86,977.16, this being the fifth of his gifts to the Foundation. The total book value of the Foundation fund is now $957,698.

The Foundation has been assisting in a wide range of technical researches sponsored by the founder societies. Some of the principal groups now in progress are: ASCE—soil mechanics and foundations, hydraulics; AIME—alloys of iron, barodynamic problems; ASME—critical pressure steam boilers, fluid meters, lubrication, cottonseed processing, rolling steels; AIEE—stability of impregnated paper insulation; AIEE and AWS—welding; University of California—plastic flow of concrete; New York University—wind direction and velocity.

Assistance in non-technical matters related to engineering has been granted to the Engineers' Council for Professional Development and the Personnel Research Federation.

An abstract of the annual report of the Engineering Foundation for the year which ended September 30, 1938, was published in the December 1938 issue of Electrical Engineering, pages 519–21.

Engineering Societies Library

The Engineering Societies Library, which was formed by combining the separate libraries of the four national societies of civil, mining and metallurgical, mechanical, and electrical engineers, and the preparation of a composite card catalog, has been expanded as a single engineering library, which probably constitutes the best collection of its type in the United States.

On September 30, 1938, the library had 144,262 volumes, 7,408 maps, 4,391 bibliographies. Books, pamphlets, and maps totaling 14,041 were received during the year ending at that time. Current issues of 1,369 periodicals were received. Work progressed rapidly on a classified index to periodicals, and the index now contains more than 225,000 references to articles published since 1927.

Special services rendered by the library include: photoprints, searches, abstracts, translations, bibliographies, book loans by mail, etc. An abstract of the annual report of the library appeared on page 519 of Electrical Engineering for December 1938.

Engineers' Council for Professional Development

This council was organized in 1932 to engage in activities leading to the enhancement of the professional status of the engineer. It includes three representatives of each of the seven participating organizations: the national societies of chemical, civil, electrical, mechanical, and mining and metallurgical engineers, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

The principal activities of ECPD include programs for the guidance of young individuals thinking of entering the engineering field, the accrediting of curricula of engineering schools, encouragement and assistance to individuals in their engineering and cultural studies during several years after graduation, and the development of criteria for indicating the attainment of the status of an engineer.

At the annual meeting held on October 22, 1938, the committee on engineering schools submitted recommendations on 63 additional curricula, bringing the total number to 679 curricula in 136 institutions. Of these, 392 were accredited, 107 were not accredited, and action on one was deferred. The complete list of curricula thus far accredited appeared in the December 1938 issue of Electrical Engineering, page 514.

Comprehensive information regarding other committee reports and the various other matters considered and acted upon at the annual meeting appeared in the same issue, pages 513–16.

Representatives

The Institute has continued its representation upon many joint committees and national bodies, with which it co-operates in a wide range of activities of interest and importance to engineers and others.

A list of representatives was published in the September 1938 issue of Electrical Engineering and in the 1939 Year Book.

Finance Committee

The committee, as usual, recommended a detailed budget to the board of directors, passed upon the expenditures for various purposes, made recommendations regarding delinquent members, and performed the other duties prescribed for it in the constitution and by-laws.

Haskins and Sells, certified public accountants, have audited the books, and their report follows.

The board of directors extends to the national committees, and the District, Section, and Branch officers its deep appreciation of their continuing effective services, which have produced a high degree of activity, enthusiasm, and constructive accomplishment in all phases of Institute work. The board of directors has been much encouraged by the generous support which the members have given its efforts on their behalf.

Respectfully submitted for the board of directors.

H. H. Henline,
National Secretary

May 26, 1939

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

22 EAST 40TH STREET
NEW YORK

May 18, 1939

American Institute of Electrical Engineers,
33 West 39th Street, New York.

Dear Sirs:

We have made an examination of your balance sheet as of April 30, 1939, and of your recorded cash receipts and disbursements for the year ended that date. In connection therewith, we examined or tested your accounting records and other supporting evidence in a manner and to the extent which we considered appropriate in view of your system of internal accounting control. We present the following financial statements:

Balance Sheet, April 30, 1939 (Exhibit A).
Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value (Schedule 1).

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1939 (Exhibit B).

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1939 (Exhibit C).

In accordance with the terms of our engagement, members and other debtors were not requested to confirm to us the amounts receivable from them at April 30, 1939, and, in accordance with the usual practice of the Institute, no provision has been made for dues which may prove to be uncollectible.

In our opinion, based upon such examination and subject to the comments in the next preceding paragraph, the accompanying Exhibit A fairly presents your financial condition at April 30, 1939, and the accompanying Exhibits B and C fairly present your recorded cash receipts and your disbursements of funds, as indicated, for the year ended that date.

Yours truly,

Haskins & Sells

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Balance Sheet, April 30, 1939

Exhibit A

ASSETS		LIABILITIES	
Property Fund Investments:			
One-fourth interest in real estate and other assets of United Engineering Trustees, Inc., exclusive of trust funds	$498,448.48		
Equipment:			
Library—volumes and fixtures	37,296.37		
Office furniture and fixtures (less reserve for depreciation, $29,255.45)	5,398.38		
Works of art, etc.	3,001.35		
Securities—at cost (market quotation value, $9,597.17)—Schedule 1	10,032.17		
Cash (see Exhibit C)	32.83		
Total property fund investments	$554,209.58		
Restricted Fund Investments:			
Securities—at cost, less reserve for securities of doubtful value (Market quotation value, $178,881.07)—Schedule 1	$195,994.82		
Cash (see Exhibit C)	15,738.53		
Accrued interest receivable	145.16		
Total restricted fund investments	211,878.51		
Current Assets:			
Cash (see Exhibit B)	$ 61,988.30		
Accounts receivable:			
Members—for dues	19,733.35		
Advertisers	389.25		
Miscellaneous	2,419.80		
Accrued interest on investments	1,733.97		
Inventories:			
TRANSACTIONS, etc.	1,984.00		
Text and cover paper	5,560.65		
Work in process (May issue of ELECTRICAL ENGINEERING)	3,061.14		
Badges	920.92		
Total current assets	97,791.38		
		Property Fund Reserve	$554,209.58
		Restricted Fund Reserves:	
		Reserve Capital Fund	$191,634.04
		Life Membership Fund	9,168.34
		International Electrical Congress of St. Louis Library Fund	5,521.17
		Lamme Medal Fund	4,514.73
		Mailloux Fund	1,040.23
		Total restricted fund reserves	211,878.51
		Current Liabilities—Accounts payable	11,423.26
		Deferred Income:	
		Dues received in advance	$ 3,792.27
		Entrance fees and dues advanced by applicants for memberships	539.66
		Deferred credits and other unallocated receipts	428.32
		Subscriptions for TRANSACTIONS received in advance	8.27
		Reserve for prepaid subscriptions for ELECTRICAL ENGINEERING	8,700.00
		Total deferred income	13,468.52
		Surplus	72,899.60
Total	$863,879.47	**Total**	$863,879.47

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value, April 30, 1939

Exhibit A, Schedule 1

	Face Value of Bonds or Number of Shares of Stock	Property Fund (Equipment Replacements)	Restricted Funds: Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total
Railroad Bonds:								
Alleghany Corporation 20-year collateral trust convertible 5%, due 1949	$15,000.00		$ 10,627.50					$ 10,627.50
Baltimore & Ohio Railroad Company 6% refunding and general mortgage series C, due 1995 (certificates of deposit)	12,000.00		8,940.00			$4,330.00		13,270.00
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	3,000.00		1,477.50					1,477.50
Chicago, Burlington & Quincy Railroad Company 5% first and refunding mortgage series A, due 1971	1,000.00		1,010.00					1,010.00
Chicago & Erie Railroad Company 5% first mortgage, due 1982	1,000.00		1,105.00					1,105.00
Chicago & Northwestern Railway Company 6½%, due March 1, 1936	9,000.00		7,202.50					7,202.50
Cleveland Union Terminals Company 5% sinking fund series B, due 1973	4,000.00	$ 4,010.00						
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974 (certificates of deposit)	10,000.00		9,818.75					9,818.75
New York Central Railroad Company 5% refunding and improvement mortgage series C, due 2013	6,000.00		5,742.50					5,742.50
Northern Pacific Railway Company 6% refunding and improvement mortgage series B, due 2047	10,000.00		10,962.50					10,962.50
Pennsylvania Railroad Company 30-year secured serial 4%, due 1944	6,000.00		5,337.50		$1,067.50			6,405.00
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950 (certificates of deposit)	6,000.00		5,497.50					5,497.50
Southern Pacific Company Oregon Lines 4½% first mortgage series A, due 1977	1,000.00				996.25			996.25
Texas and Pacific Railway Company general and refunding series B 5%, due 1977	5,000.00			$5,306.25				5,306.25
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00		7,225.00					7,225.00
Total railroad bonds—(FORWARD)		$ 4,010.00	$ 74,946.25	$5,306.25	$2,063.75	$4,330.00		$ 86,646.25

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value, April 30, 1939

Exhibit A, Schedule 1 (Concluded)

	Face Value of Bonds or Number of Shares of Stock	Property Fund (Equipment Replacements)	Restricted Funds: Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total
Total Railroad Bonds—FORWARD		$ 4,010.00	$ 74,946.25	$5,306.25	$2,063.75	$4,330.00		$ 86,646.25
Public Utility Bonds:								
American Gas & Electric Company 5% debenture, due 2028	6,000.00		$ 6,397.50					$ 6,397.50
Monongahela-West Pennsylvania Public Service Company 6% debentures, due 1965	8,000.00		8,660.00					8,660.00
New York Telephone Company first and general mortgage 4½%, due 1939	1,000.00						$1,000.00	1,000.00
Total public utility bonds			$ 15,057.50				$1,000.00	$ 16,057.50
Industrial and Miscellaneous Bonds, Etc.:								
Fidelity Union Title and Mortgage Guaranty Company first mortgage certificates (on property 75-79 Prospect Street, East Orange, N. J.), 4%, due 1944	$14,507.49	$ 967.17	$ 13,540.32					$ 13,540.32
General Motors Acceptance Corporation 3¼%, due 1951	7,000.00		7,140.00					7,140.00
United States Steel Corporation debentures 3¼%, due 1948	8,000.00		8,240.00					8,240.00
Total industrial and miscellaneous bonds, etc.		$ 967.17	$ 28,920.32					$ 28,920.32
Municipal Bonds—New York City 4½% corporate stock, due 1957	2,000.00				$2,204.05			$ 2,204.05
United States Government Bonds and Notes:								
Federal Farm Mortgage 3%, due 1949/44	12,000.00		$ 12,405.00					$ 12,405.00
Treasury Bonds 3¼%, due 1941	10,000.00		10,650.00					10,650.00
Treasury Bonds 2¾%, due 1947/45	10,000.00		10,409.38					10,409.38
Treasury Bonds 3¼%, due 1943/40	10,000.00		10,537.50					10,537.50
Treasury Bonds 3¼%, due 1943/41	10,000.00		10,681.25					10,681.25
Treasury Notes 2% series B, due September 15, 1942	21,000.00		21,756.57					21,756.57
Total United States Government bonds and notes			$ 76,439.70					$ 76,439.70
Capital Stocks:								
Commonwealth Edison Company	48 shares		$ 2,892.00					$ 2,892.00
Commercial Investment Trust Corporation 4¼% preferred, series of 1935	100 "		10,100.00					10,100.00
Consolidated Edison Company of New York, Inc. $5.00 cumulative preferred	30 "	$ 3,060.00						
International Match Realization Co., Ltd. voting trust certificates for capital shares of International Match Corporation	6 "		2,274.15					2,274.15
Public Service Corporation of New Jersey $5.00 preferred	30 "		2,958.75					2,958.75
United Gas Improvement Company $5.00 preferred	30 "	1,995.00	997.50					997.50
Total capital stocks		$ 5,055.00	$ 19,222.40					$ 19,222.40
Total		$10,032.17	$214,586.17	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$229,490.22
Less Reserve for Securities of Doubtful Value:								
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	$ 3,000.00		$ 1,477.50					$ 1,477.50
Chicago & Northwestern Railway Company 6½%, due March 1, 1936	9,000.00		7,202.50					7,202.50
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974	10,000.00		9,818.75					9,818.75
International Match Realization Company, Ltd. voting trust certificates for capital shares of International March Corporation	6 shares		2,274.15					2,274.15
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950	$ 6,000.00		5,497.50					5,497.50
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00		7,225.00					7,225.00
Total reserve for securities of doubtful value			$ 33,495.40					$ 33,495.40
Total Securities, Less Reserve		$10,032.17	$181,090.77	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$195,994.82
Total Property Fund Securities		$10,032.17						
Total Restricted Funds Securities			$181,090.77	$5,306.25	$4,267.80	$4,330.00	$1,000.00	$195,994.82

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1939

Exhibit B

Cash on Deposit With The National City Bank of New York, May 1, 1938		$ 49,616.89
Receipts:		
Dues (including $86,226.00 allocated to ELECTRICAL ENGINEERING subscriptions)	$191,719.44	
Advertising	26,360.83	
TRANSACTIONS subscriptions	8,262.45	
ELECTRICAL ENGINEERING subscriptions	14,990.85	
Miscellaneous publications (preprints, standards, etc.)	8,912.95	
Student fees	11,297.50	
Entrance fees	7,023.70	
Membership badges	1,808.40	
Transfer fees	770.00	
Interest on investments, less purchased interest	8,981.91	
Miscellaneous	16.90	
Total receipts		280,144.93
Total		$329,761.82
Disbursements:		
Publication expense:		
ELECTRICAL ENGINEERING	$ 72,893.80	
TRANSACTIONS	8,843.13	
YEAR BOOK	6,567.96	
Miscellaneous publications (preprints, standards, etc.)	12,323.68	
Institute meetings	13,623.38	
Institute Sections	33,853.28	
Institute Branches	3,265.05	
Edison Medal committee	299.11	
Finance committee	1,600.00	
Headquarters committee	34.75	
Membership committee	8,082.47	
Standards committee	6,413.15	
Technical committee	286.41	
Traveling expenses:		
Geographical Districts:		
Executive committees	2,899.85	
Vice-presidents	365.79	
Branch counselors	8,036.08	
President's appropriation	34.85	
Board of directors	3,274.22	
National nominating committee	1,020.79	
Forward	$183,717.75	$329,761.82
Total—(Forward)		$329,761.82
Disbursements—(Forward)	$183,717.75	
Administrative expenses	46,221 53	
Geographical Districts—best paper prizes	185.50	
Geographical Districts—initial paper prizes	85.50	
Institute prizes	109.00	
American Engineering Council	10,500.00	
American Standards Association	1,500.00	
United Engineering Trustees, Inc.:		
Building assessment	10,984.80	
Library assessment	9,689.28	
Engineering Societies Employment Service	1,512.77	
Engineers' Council for Professional Development	435.00	
Engineering Foundation Projects:		
Welding research	250.00	
Research on impregnated paper insulation	250.00	
John Fritz Medal	201.92	
National Fire Protection Association—dues	60.00	
United States Committee of International Commission on Illumination	300.00	
Membership badges	1,503.97	
Legal services	250.00	
Miscellaneous	16.50	
Total disbursements		267,773.52
Cash on Deposit With The National City Bank of New York, April 30, 1939		$ 61 988.30

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1939

Exhibit C

		Restricted Funds					
	Property Fund (Equipment Replacements)	Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total Restricted Funds
Cash on Deposit With East River Savings Bank and The National City Bank of New York, May 1, 1938	$22.47	$ 82.06	$3,794.44	$1,024.19	$148.03	$22.23	$ 5,070.95
Receipts:							
Interest on bonds, and dividends on stocks			$ 250.00	$ 175.00	$240.00	$45.00	$ 710.00
Interest on bank balance			73.66				73.66
Proceeds from sale and redemption of securities	$10.36	$53,639.03					53,639.03
Life membership fee			288.51				288.51
Total receipts	$10.36	$53,639.03	$ 612.17	$ 175.00	$240.00	$45.00	$54,711.20
Total	$32.83	$53,721.09	$4,406.61	$1,199.19	$388.03	$67.23	$59,782.15
Disbursements:							
Annual withdrawal authorized in by-laws			$ 565.35				$ 565.35
Gold and bronze replicas of Lamme Medal and certificate					$239.30		239.30
Purchase of securities		$43,177.82					43,177.82
All other disbursements				$ 11.65		$49.50	61.15
Total disbursements		$43,177.82	$ 565.35	$ 11.65	$239.30	$49.50	$44,043.62
Balance on Deposit With East River Savings Bank and The National City Bank of New York, April 30, 1939	$32.83	$10,543.27	$3,841.26	$1,187.54	$148.73	$17.73	$15,738.53

New Officers of ASTM. Newly elected officers of the American Society for Testing Materials have been announced as follows: *president* (1939–40)—H. H. Morgan, manager rail and track fastenings department, Robert W. Hunt Company, Chicago, Ill.; *vice-president* (1939–41)—G. E. F. Lundell, chief of chemistry division, National Bureau of Standards, Washington, D. C.; *members of executive committee* (1939–41)—J. J. Allen, chief chemist, mechanical rubber goods division, Firestone Tire and Rubber Company, Akron, Ohio; R. D. Bonney, assistant manager of manufacturing, Congoleum-Nairn, Inc., Kearny, N. J.; T. S. Fuller, engineer of materials, General Electric Company, Schenectady, N. Y.; J. L. McCloud, metallurgical chemist, Ford Motor Company, Dearborn, Mich.; M. A. Swayze, director of research, Lone Star Cement Company, Hudson, N. Y.

ASTM Awards Dudley Medal. The American Society for Testing Materials has awarded the Charles B. Dudley Medal for 1938 to R. W. Carlson, associate professor of civil engineering, Massachusetts Institute of Technology, Cambridge, for his paper "Dry Shrinkage of Concrete as Affected by Many Factors." The medal is awarded for a paper of outstanding merit constituting an original contribution to research.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and the other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Some Types of Discussers

To the Editor:

The following are some types of discussers that I have met at technical meetings:

1. Instructed by the boss to say that his company has developed practically an identical gadget long ago, but discontinued making it because of the customers' complaints.

2. Condemns newfangled ideas in general and the paper by implication; says that the old things were not only fully sufficient, but actually better.

3. Says that his graduate students found the same result several years ago, but he did not deem it of sufficient importance to be published.

4. As one of the same gang, praises the paper and the author ex officio; "rubs in" a thing or two left out of the paper for commercial reasons.

5. Tells a long story of how he and Edison once tried to solve an entirely different problem. A sufferer from an irresistible "it-reminds-me" disease.

6. Pedantically puts dots over the author's i's.

7. Reads a few paragraphs of general, irrelevant nature, to justify his traveling expenses.

8. The "smart alec" type: Repeats a part of the author's paper, in different and more obscure language, to show his learning.

9. Assumes a paternal attitude of an unappreciated pioneer, who at last sees his early struggles realized.

10. Shows lantern slides of a few mysterious curves on the screen, to indicate "us too."

11. Has nothing to say and says it with much zest: "Look, I'm here, aren't you glad to see me?"

12. In an ingratiating way mentions the beautiful climate of Los Angeles.

Very truly yours,

VLADIMIR KARAPETOFF (A'03, F'12)

(Consulting Engineer, Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.)

Calculation of Resistance Steps in Starting Rheostats

To the Editor:

The calculation of the resistance steps in the starting rheostat, for a d-c motor has been considerably simplified by the use of graphical methods. Professor A. S. Langsdorf describes these methods in his "Principles of Direct Current Machines" and derives several useful relationships between the resistance values of the steps. Working along similar lines, I. Fagin, a student in our evening session, derived some expressions which I believe simplify the design of the starting box considerably.

In figure 1 is shown the usual construction used to determine the resistances of the steps. Here γ is the ratio of the peak

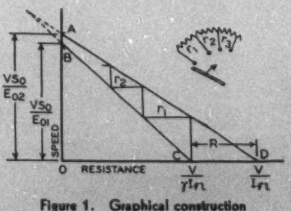


Figure 1. Graphical construction

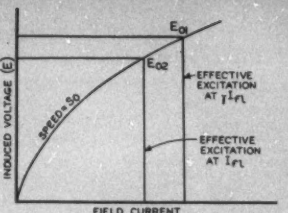


Figure 2. Saturation curve at speed S_0

current permissible to the full-load current experienced during the starting cycle. This diagram will give the steps r_1, r_2, r_3, etc. It should be noted that the ratio of the ordinates at the origin is given by the following expression:

$$\frac{OA}{OB} = \frac{E_{01}}{E_{02}} = K \qquad (1)$$

Essentially the ratio "K" is the ratio of the field flux existing at γI_{f1} armature amperes to the flux existing at I_{f1} armature amperes. It is obtainable from the saturation curve of the machine and may be greater than, smaller than, or equal to unity, depending on whether magnetizing, demagnetizing, or neutral conditions exist in the field. "K" may be obtained from the saturation curve as shown in figure 2.

From a careful consideration of the symmetries of the graphical construction, it may be shown that:

$$\frac{R}{r_1} = \frac{r_1}{r_2} \text{ etc.} = \frac{OD}{OC} \times \frac{OB}{OA} = \gamma \times \frac{1}{K} \qquad (2)$$

Also,

$$R = \frac{V}{I_{f1}} - \frac{V}{\gamma I_{f1}} = \frac{V}{I_{f1}}\left(\frac{\gamma - 1}{\gamma}\right) \qquad (3)$$

Using these relationships, it is now possible to design the steps in the starting box. The current ratio during starting is fixed at γ and the ratio K is found from the saturation curve, or estimated, if need be. The resistance R is computed from equation 3. The steps in the starting box are then obtained as follows:

$$r_1 = \frac{K}{\gamma} R$$

$$r_2 = \frac{K}{\gamma} r_1$$

$$r_3 = \frac{K}{\gamma} r_2$$

etc., and steps are added until:

$$r_1 + r_2 + r_3, \text{ etc.} = \frac{V}{\gamma I_{f1}}$$

By means of this procedure, the starting box may be calculated expeditiously for any type of direct current motor, shunt, compound, or series, without the necessity of constructing a scale diagram.

Very truly yours,

JOHN RAGAZZINI (A'33)

(Tutor, College of The City of New York, New York, N. Y.)

Personal Items

G. W. Thaxton (M'36) has been appointed chief engineer of the Rural Electrification Administration, Washington, D. C. Mr. Thaxton was born in Lake, Miss., in 1894, and received the degree of bachelor of science in electrical engineering from Mississippi State College in 1916. He was instructor in electrical engineering and assistant superintendent of the college generating plant at Mississippi State College, State College, Miss., 1916–17, and spent the following year as electrical assistant, United States Signal Corps, New York, N. Y. From 1918 to 1920 he was employed in the electrical engineering department of the Tennessee Coal, Iron, and Railroad Company. He was assistant professor of electrical engineering at Georgia School of Technology, Atlanta, from 1921 to 1924. During the next four years he was a special sales engineer for Westinghouse Electric and Manufacturing Company. In 1928 he was engaged in setting up operating organization and procedure for the Mississippi Utilities Company, after which he became agent for banking interests in acquiring and unifying various southern public-utility plants and systems. Out of these efforts was developed the Mid-South Public Service Company, of which Mr. Thaxton was vice-president and general manager, and later president, and from which he withdrew in 1931 to private consulting practice. In 1933 he became division engineer for the Tennessee Valley Authority at Tupelo, Miss., also serving as Mississippi district manager of the Electric Home and Farm Authority. He was transferred to the Rural Electrification Administration in 1935, as regional engineer, and except for a leave of absence as consulting electrical engineer for Chase Brass and Copper Company, continued in that post until his recent appointment. He is a member of Tau Beta Pi.

C. F. Wagner (A'20, M'27) has received the 1938 AIEE national prize award for best paper in engineering practice for his paper "Unsymmetrical Short Circuits on Water-Wheel Generators Under Capacitive Loading." Mr. Wagner was born March 20, 1895, in Pittsburgh, Pa. He received the degree of bachelor of science in electrical engineering at Carnegie Institute of Technology in 1917, and later did graduate work at the University of Chicago. Since 1918 he has been with the Westinghouse Electric and Manufacturing Company, at East Pittsburgh, Pa., engaged on research and development problems in various departments. He was first in the material and process engineering department, and in 1924 was transferred to the newly organized transmission engineering department, where he continued until 1933. For the next two years he was engaged in the development of rectifiers and inverters in the research department, and as central station engineer 1935–38 carried on special studies on transmission problems. In 1938 he was appointed consulting transmission engineer, the position which he now holds. He is co-author of a book on "Symmetrical Components" and author and co-author of many papers on technical subjects, and has received the award of the George Montefiore Foundation. He is a member of the AIEE committee on power transmission and distribution, and a member of the American Standards Association and various sub-committees.

C. W. Kellogg (A'19, M'23) has been elected the first permanent salaried president of the Edison Electric Institute. Mr. Kellogg, who has been president of the Institute since 1936, is resigning as chairman of Engineers Public Service Company, New York, to devote his attention to the newly created position, but will continue to be active in the affairs of the companies of which he is a director. Born in Philadelphia, Pa., February 27, 1880, he studied electrical and mechanical engineering at Massachusetts Institute of Technology, receiving the degrees of bachelor of science in 1902 and master of science in 1903. Throughout his professional career he has been engaged in public-utility work, as manager, Edison Electric Illuminating Company of Brockton, Mass., 1905; manager, El Paso (Tex.) Electric Railway Company, 1905–14, and manager of Eastern Texas Electric Company properties in Beaumont and Port Arthur, 1911–14; manager, Mississippi River Power Company, Keokuk, Iowa, 1914–19. He was district manager of the midwest district of Stone and Webster, Inc., 1916–19, and from 1919 to 1925 was engineer and consultant in connection with eastern properties of the company, with headquarters in Boston, Mass. He was made president of the newly organized Engineers' Public Service Company, New York, N. Y., in 1925, and in 1933 became chairman of the board.

K. S. Wyatt (A'32) co-author of the paper "Mechanical Uniformity in Paper-Insulated Cables" with D. L. Smart (A'37) and J. M. Reynar, has received the 1938 AIEE national prize award for best paper in theory and research. Mr. Wyatt was born in Cambridge, Mass., September 24, 1900. He attended Mount Allison University, Sackville, N. B., Canada, receiving the degrees of bachelor of arts (1921) and bachelor of science in 1922, and later did graduate work at Harvard University and at the University of Toronto, in the latter case on a fellowship from the National Research Council of Canada. He was an assistant research chemist for the Carborundum Company, Niagara Falls, N. Y., in 1922–23. The Detroit Edison Company, Detroit, Mich., employed him in 1928 as research engineer on cable insulation. He continued in that position until 1938, when he became technical director of the Enfield Cable Works, Ltd., Enfield, England, where he is responsible for technical developments in design, manufacture, and installation, and also directs research. Mr. Wyatt is a member of the American Chemical Society and has been associated with a number of national committees on cables and insulation. He is author and co-author of many papers on cable insulation.

H. S. Bennion (M'27) has been elected vice-president and managing director of the Edison Electric Institute, New York, N. Y. He was formerly assistant managing director. Mr. Bennion was born in Vernon, Utah, in 1889, and is a graduate of the United States Military Academy (1912) and the United States Engineering School (1915). From 1915 to 1920 he was with the United States Army, with engineer troops at Galveston, Tex., 1915; with the military survey of Luzon, Philippine Islands, 1915–17, being in charge of the survey the latter part of that time; commander of the First Battalion, Second Engineers, American Expeditionary Forces, 1917; chief of Camouflage Service, AEF, 1917–19; engi-

H. S. BENNION C. W. KELLOGG K. S. WYATT C. F. WAGNER G. W. THAXTON

S. J. ROSCH

D. L. SMART

C. F. BOWMAN

neering services in connection with road work, supplies, sales, United States Liquidation Commission, 1919–20. He was assistant chief engineer, Federal Power Commission, Washington, D. C., 1920–24, and during the next two years district engineer of the fourth Mississippi district at New Orleans, La., and member of the United States Spillway Board. He became director of engineering for the National Electric Light Association, New York, N. Y., in 1926, and assistant managing director in 1932, continuing in that position when that organization was succeeded by the EEI.

D. L. Smart (A'37) co-author of the paper "Mechanical Uniformity of Paper-Insulated Cables" with K. S. Wyatt (A'32) and J. M. Reynar, has received the 1938 AIEE national prize award for best paper in theory and research. Born in Boston, Mass., March 4, 1903, Mr. Smart received the degree of bachelor of science in mechanical engineering at Purdue University in 1925. From 1925 to 1927 he was employed by Consumers Power Company, first as a junior engineer at the Milwaukee (Mich.) plant, then with the personnel department at that plant and Garfield substation, Flint, Mich., and finally as combustion engineer at Grand Rapids, Mich. During the next two years he was power plant combustion engineer for the Chevrolet Motor Company, Detroit, Mich. Since 1929 he has been with the research department of the Detroit Edison Company, engaged in materials testing and special research on problems related to electrical insulation. He has been head of the mechanical division of the research department since 1937. He is a member of the American Society of Mechanical Engineers and of the Engineering Society of Detroit.

C. F. Bowman (A'24, M'30) has been made chief engineer for the Montana Railroad and Public Service Commission, with headquarters in Helena. Mr. Bowman graduated from the University of Nebraska in 1923 with the degrees of bachelor of arts and bachelor of science in electrical engineering, and received the degrees of master of science in electrical engineering from Purdue University in 1928, and of electrical engineer from Montana State College in 1932. He was an instructor in electrical engineering at Purdue University, Lafayette, Ind., from 1923 to 1929, when he became assistant professor of electrical engineering at Montana State College, Bozeman. He was later given the rank of associate professor and held that position until his present appointment. He also maintained a consulting engineering practice. He is chairman of the AIEE Montana Section.

S. J. Rosch (A'15) has received the 1938 AIEE national prize award for initial paper for his paper "The Current-Carrying Capacity of Rubber Insulated Cables." Mr. Rosch, who is manager, insulated products development, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., has been associated with the cable industry for 28 years. He is a member of the American Standards Association, the American Society for Testing Materials, International Association of Electrical Inspectors, Insulated Power Cable Engineers Association, American Transit Association, and author of many articles on technical subjects.

E. I. Green (A'23, M'30) with co-author C. W. Green (A'10, M'26) has received honorable mention in the 1938 AIEE national prize award for best paper in engineering practice, for the paper "A Carrier Telephone System for Toll Cables." Mr. Green was born in St. Louis, Mo., in 1895, and received the degree of bachelor of arts at Westminster College in 1915. Later he did graduate work at the University of Chicago and in 1921 received the degree of bachelor of science in electrical engineering from Harvard University. He began his engineering career in 1920 with the General Electric Company at Pittsfield, Mass., and in 1921 entered the department of development and research of the American Telephone and Telegraph Company, New York, N. Y., engaging in development work on carrier telephone and telegraph systems. In 1934 he became associated with the Bell Telephone Laboratories, where he is at present a carrier telephone engineer. He is a member of the Institute of Radio Engineers and the Acoustical Society of America, and author and co-author of various technical papers.

H. W. Wahlquist (M'36) with co-author T. A. Taylor (A'30, M'36) has received honorable mention in the 1938 AIEE national prize award for initial paper for the paper "Noise Co-ordination of Rural Power and Telephone Systems." Mr. Wahlquist was born in Duluth, Minn., in 1895, and received the degrees of bachelor of science (1921) and electrical engineer (1922) from the University of Minnesota. He was employed by the Twin City Electric Company, Minneapolis, Minn., from 1922 to 1925, when he became an assistant engineer for the Northern States Power Company of Minneapolis. He represented the company in the Minneapolis Joint Use Investigation, and the following year, as assistant engineer for the National Electric Light Association, represented the power industry in the Elmira (N. Y.) Joint Use Investigation. He continued with the NELA until it was succeeded by the Edison Electric Institute, and is now an assistant engineer for the latter, engaged particularly with the problem of inductive co-ordination of power and communication systems. He was a member of the joint committee on development and research of the Edison Electric Institute and the Bell Telephone System.

L. R. Mapes (M'29, F'37) general manager, state area, Illinois Bell Telephone Company, Chicago, has been elected president of the Western Society of Engineers. A native (1892) of Middletown, N. Y., Mr. Mapes received the degree of electrical engineer from Columbia University in 1913. He was employed in the engineering department of the American Telephone and Telegraph Company, New York, until 1925, when he was transferred to the Illinois Bell Telephone Company as building and equipment engineer in charge of design and construction of telephone buildings and switchboards. In 1928 he was made chief engineer for the Chicago area and held that position until 1938 when he became general manager of the state area. Mr. Mapes is a director of the AIEE, and has also been chairman of the Chicago Section (1932–33) and a member of the committee on transfers (1934–36). He has been successively chairman of the electrical section, a trustee, and a vice-president of the Western Society of Engineers, before his election as president.

N. S. Braden (A'09, M'20) has been appointed vice-chairman of the board of Canadian Westinghouse Company, Ltd., Hamilton, Ont., Canada. He has been a vice-president of the company since 1919. Mr. Braden was born in Indianapolis, Ind., June 15, 1869, and attended Whitman College, Walla Walla, Wash. He was employed as an apprentice in 1892 by the Jenney Electric Motor Company, and later became a construction and sales engineer for the company at Cleveland, Ohio. In 1899 he became a sales engineer with the Cleveland office of the Westinghouse Electric and Manufacturing Company, and in 1903 was appointed district manager of the same office. He was made manager of the sales department of Canadian Westinghouse Company, Ltd., in 1904 and continued in that position until he was appointed third vice-president in executive charge of all commercial activities of the company.

T. A. Taylor (A'30, M'36) co-author of the paper "Noise Co-ordination of Rural Power and Telephone Systems" with H. W. Wahlquist (M'36), has received honorable men-

tion in the 1938 AIEE national prize award for initial paper. Mr. Taylor was born in Brooklyn, N. Y., in 1906 and graduated from Harvard University in 1928 with the degree of bachelor of science in electrical engineering. From 1928 to 1934 he was an engineer in the department of development and research of the American Telephone and Telegraph Company, New York, N. Y., engaging in field and laboratory work on inductive co-ordination of power and telephone systems, and acting as a member of the joint committee on development and research of the Edison Electric Institute and the Bell Telephone System. In 1934 he became a member of the technical staff of the Bell Telephone Laboratories, New York, continuing his work on inductive coordination. He is a member of Tau Beta Pi.

J. D. Kennedy (A'06) general telephone sales manager of Western Electric Company, New York, N. Y., will retire September 1, 1939. Mr. Kennedy graduated in engineering from Cornell University in 1898 and the following year became associated with Western Electric as a telephone engineer in New York. He has been with the company continuously ever since. He supervised the central office equipment engineering force in Chicago, was later transferred to Philadelphia, where he was in charge of distribution, and in 1918 returned to head the merchandise organization of the Hawthorne Works at Chicago. For four years he had charge of engineering all switchboard equipment made for the Bell System by Western Electric. He became head of the distributing department for the western half of the United States in 1926, and in 1927 assumed his present position in charge of the company's national distribution organization.

J. A. Kahn (A'21) has been made commercial vice-president of General Electric Supply Corporation, Salt Lake City, Utah. He was formerly Rocky Mountain district manager there. Mr. Kahn was born in Morrison, Ill., in 1872. He has been associated with the electrical industry since 1918, when he became connected with the Capital Electric Company, Salt Lake City, of which he was first general manager and later president. He had been district manager of the General Electric Supply Company in Salt Lake City for 11 years before his present appointment. He was one of the founders of the Rocky Mountain Electrical Cooperative League, predecessor of the Electrical League of Utah, and its first president.

William McClellan (A'04, F'12) has been made president of the Union Electric Company of Missouri, with headquarters at St. Louis. Doctor McClellan, who holds the degrees of bachelor of science (1900) and doctor of philosophy (1903) from the University of Pennsylvania, has been associated with that institution as instructor, dean of the Wharton School of Finance and Commerce, and trustee. He has been an executive of the Campion-McClellan Company, the firm of Paine, McClellan, and Campion, the Cleveland Electric Illuminating Company, McClellan and Junkersfield, Stone and Webster Engineering Corporation, and William McClellan and Company, Ltd. He resigned the position of president of the Potomac Electric Company, Washington, D. C., to accept his present appointment. He has been a manager, vice-president, and president of the AIEE, and is president of the American Engineering Council.

R. G. Warner (A'19, M'20) has been appointed to the engineering staff of the United Illuminating Company, New Haven, Conn. He was formerly assistant professor of electrical engineering at Yale University, New Haven. Mr. Warner received the degrees of bachelor of philosophy (1914) and electrical engineer (1920) from Yale University. From 1914 to 1916 he was with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in the student course and later as switchboard engineer. He became an instructor in electrical engineering at Yale in 1916 and continued in the department until his recent appointment. He has been electrical engineer for the Connecticut Public Utilities Commission since 1930, and has also been a consulting engineer for several private companies. He is past chairman (1931–32) of the AIEE Connecticut Section, and a member of Sigma Xi and Tau Beta Pi.

R. W. Sorensen (A'07, F'19) has received the 1938 AIEE national prize award for best paper in public relations and education, for his paper "The Economic Status of the Engineer." Doctor Sorensen is professor and head of the department of electrical engineering at California Institute of Technology, Pasadena. He is a director of the AIEE, a past vice-president, chairman of the committee on Student Branches, and member of the Edison Medal committee and the committee on economic status of the engineer. A biographical sketch of Doctor Sorensen appeared in the October 1938 issue, page 434.

C. W. Green (A'10, M'26) co-author of the paper "A Carrier Telephone System for Toll Cables" with E. I. Green (A'23, M'30), has received honorable mention in the 1938 AIEE national prize award for best paper in engineering practice. A native (1884) of Waukegan, Ill., Mr. Green graduated in electrical engineering from the University of Wisconsin in 1907 with the degree of bachelor of science. He taught in the electrical-engineering department of Massachusetts Institute of Technology from 1907 to 1917, first as instructor, and later as assistant professor. During the World War he served in the United States Army, attaining the rank of major. He was a telephone engineer for the Western Electric Company 1919–24, and since 1924 has been with the Bell Telephone Laboratories, Inc., New York, N. Y. His present position is carrier telephone engineer. He is a member of Tau Beta Pi.

J. L. C. Löf (Enrolled Student) graduate student at Massachusetts Institute of Technology, has received the 1938 AIEE national prize award for Branch paper, for his paper "A Method for Determining the Efficiencies of Small Motors From the Heat Due to Eddy Currents." Mr. Löf was born in Denver, Colo., December 11, 1915. He received the degree of bachelor of science in electrical engineering from the University of Denver and is studying for the degree of master of science in electrical engineering at Massachusetts Institute of Technology.

Arch Robison (A'12, M'20) has been appointed chief engineer for the Public Utilities Commission of Ohio, with headquarters at Columbus. After graduating in electrical engineering at the University of Minnesota in 1909, Mr. Robison was employed in hydroelectric projects and mining in Montana. In 1918 he became assistant construction superintendent on the United States Nitrate Plant at Muscle Shoals, Ala., for the J. G. White Engineering Corporation, and continued in engineering activities for that company and others until he became vice-president and general manager of the Central Ohio Light and Power Company, Findlay, at its organization. In 1938 he became city manager of Celina, Ohio, giving up that position to accept his present appointment.

F. H. Lane (M'23, F'37) manager, engineering division, Public Utility Engineering and Service Corporation, Chicago, Ill., has been elected third vice-president of the Western Society of Engineers. Mr. Lane studied electrical and mechanical engineering at the Lewis Institute, Chicago, and received the degree of bachelor of science in 1904. He was employed in engineering capacities by H. M. Byllesby and Company and its successor, the Byllesby Engineering and Man-

J. A. KAHN

J. L. C. LÖF

Bachrach

R. W. SORENSEN

agement Corporation, from 1904, becoming manager of engineering and construction of the latter in 1917, and continuing in his present position after the formation of the successor company, Public Utility Engineering and Service Corporation, in 1936. He is a director of the AIEE and a member of the American Society of Mechanical Engineers.

A. H. Kidder (A'29) with co-author F. R. Ford (A'19, M'28) has received first prize in the James H. McGraw awards of the Edison Electric Institute, for the paper "Increased Loading of Apparatus and Lines Permits Practical Economies." Mr. Kidder is assistant engineer of system planning, transmission, and distribution, Philadelphia Electric Company, Philadelphia, Pa. He received the degrees of bachelor of science (1922) and master of science (1923) in electrical engineering from Massachusetts Institute of Technology, and spent a year in the compressor engineering department of the General Electric Company. Since 1923 he has been associated with the Philadelphia Electric Company, giving special attention to transmission problems.

E. G. Fox (A'12, M'20) vice-president, Freyn Engineering Company, Chicago, Ill., has been elected second vice-president of the Western Society of Engineers. Mr. Fox graduated in electrical engineering at the University of Wisconsin in 1908 and held engineering positions with various electrical manufacturing concerns until 1920, when he became a power and electrical engineer for the Freyn Engineering Company. From 1928 to 1933 his headquarters were in Leningrad, USSR, where he was concerned with the development of the iron and steel industry. He became a vice-president in 1934. He is a member of the Association of Iron and Steel Engineers, and author of books on technical subjects.

I. A. Yost (A'36) has been appointed manager of engineering of the lighting division of Westinghouse Electric and Manufacturing Company, with headquarters at Cleveland, Ohio. After graduating from Pennsylvania State College in 1924 with a bachelor of science degree in electrical engineering, Mr. Yost entered the Westinghouse student course at East Pittsburgh, Pa., and the next year was assigned to the illuminating engineering section. He has continued with the lighting division ever since, with headquarters at South Bend, Ind., 1927–30, and at Cleveland since 1930. Before his present appointment he was assistant manager of engineering of the lighting division.

F. R. Ford (A'19, M'28) co-author of the paper "Increased Loading of Apparatus and Lines Permits Practical Economies" with A. H. Kidder (A'29), has received first prize in the James H. McGraw awards of the Edison Electric Institute. Mr. Ford is assistant inside plant engineer, Philadelphia Electric Company, Philadelphia, Pa. He graduated in mechanic arts (1914) and in electrical engineering (1916) from Drexel Institute, and in 1916 entered the special training course of the Philadelphia Electric Company. Except for service in the United States Army during the World War, he has been with the company ever since.

F. E. Young, Jr. (A'32) has been appointed apparatus and supplies sales manager of the Salt Lake City (Utah) branch of Westinghouse Electric Supply Company. Mr. Young received the degree of bachelor of science in electrical engineering from the University of Utah in 1930, and entered the student course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. He has been a sales engineer for Westinghouse Electric Supply Company in Salt Lake City for some years prior to his present appointment.

Charles Dunn (A'36) has been appointed an associate electrical engineer on the Bonneville Dam Project, Portland, Ore. Since 1930 he has been electrical engineer with the Central Arizona Light and Power Company, Phoenix, Ariz. Mr. Dunn received the degrees of bachelor of electrical engineering (1927) and electrical engineer (1937) from the University of Arkansas. He was a student engineer for the Commonwealth Edison Company of Chicago 1927–28, and field engineer for the Public Service Company of Northern Illinois 1928–30.

J. F. Calvert (A'27, M'35) has received honorable mention in the 1938 AIEE national prize award for best paper in theory and research for his paper "Amplitudes of the Magnetomotive Force Harmonics for Fractional Slot Windings." Doctor Calvert is head of the electrical-engineering department at Northwestern University, Evanston, Ill. A biographical sketch of him appeared in the April issue, page 183.

J. A. Mayer (A'37) has been appointed assistant general power apparatus sales manager of the Graybar Electric Company, with headquarters in New York, N. Y. He was formerly manager for the company at Cleveland, Ohio. Mr. Mayer has been associated with the Graybar company since 1920, and before that time was a division equipment engineer for the Southwestern Bell Telephone Company, St. Louis, Mo.

H. L. Hildenbrand (A'38) has been made New York sales representative of the Esterline-Angus Company, Inc., manufacturers of electrical instruments. He has been associated with the sales department of that organization since 1933, formerly as district representative for western Pennsylvania, eastern Ohio, and West Virginia.

T. S. Teague (A'37) has been employed as high-voltage laboratory assistant by the Locke Insulator Corporation, Baltimore, Md. He was formerly a student engineer for General Electric Company, Schenectady, N. Y.

Obituary

Arthur Edwin Kennelly (A'88, M'99, F'13, HM'33) professor emeritus of electrical engineering at Harvard University and Massachusetts Institute of Technology, died April 18, 1939, in Boston, Mass. Doctor Kennelly was past-president (1898–1900) of the AIEE, Edison Medalist, and recipient of numerous honors in the United States and other countries. A complete biographical sketch will appear in the August issue.

Frederick Horace Tibbetts (M'30) consulting engineer, San Francisco, Calif., died in August 1938, according to report recently received. Born in Oshkosh, Wis., April 28 1882, he received the degrees of bachelor of science (1903) and master of science (1905) from the college of liberal arts, University of Pacific, and bachelor of science (1904) and master of science (1906) in civil engineering from the University of California. His engineering career began in 1904 as assistant on United States irrigation and drainage investigations. From 1906 to 1911 he was an instructor and later assistant professor of civil engineering at the University of California, Berkeley. In 1909 he became a member of the firm of Haviland and Tibbetts, civil engineers, later the Haviland, Dozier, and Tibbetts Construction Company, in general charge of design work, and of the San Francisco office. He continued with the company until 1917, when he set up private practice in San Francisco as a civil and consulting engineer, serving as chief engineer on numerous reclamation, irrigation, and power projects in California, Arizona, Nevada, and Oregon; on hydroelectro power developments in Alaska for the Anchorage Light and Power Company; consulting engineer on various projects including the Roosevelt Water Conservation District of Arizona, Santa Clara Valley Water Conservation District, and for the Alameda Sugar Company and the Union Sugar Company. He was a member of the American Society of Civil Engineers, Sigma Xi, Tau Beta Pi, and Sigma Iota Phi.

Edward Louis Hirt (A'18) mechanical engineer, Canadian and General Finance Company, Ltd., Toronto, Ont., Canada, died May 28, 1939. He was born in Arlington, Mass., January 3, 1890, and received the degree of mechanical engineer from Columbia University in 1913. He began his engineering career as an apprentice at the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., and the same year became an inspector for the Pearson Engineering Corporation, New York, N. Y. In 1914 he went to Tremp, Spain, as assistant to the resident engineer, for the Ebro Irrigation and Power Company, Barcelona. For the next two years he was employed as master mechanic by the Toronto Power Company at Niagara Falls, Ont., Canada, and in 1916 he became assistant to the vice-president of the Pearson Engineering Corporation, in charge of the engineering department. After a few months as mechanical engineer for Shewan Tomes and Company, New York, purchasing equipment for export to the Orient, he was employed by the Bethlehem Shipbuilding Corporation, South Bethlehem, Pa., on application of electric welding to shipwork. In 1921 he was employed as a mechanical engineer by the Canadian and General Finance Company, which acts as engineers and purchasing agents for a group of public-utility companies in Brazil and Mexico, and continued with that organization until his death.

William Clifford Stevens (A'11, M'13, F'20) secretary and vice-president in charge of engineering, Cutler-Hammer, Inc., Milwaukee, Wis., died May 15, 1939. He was born

in Portland, Maine, April 20, 1884, and graduated in mechanical engineering at Cornell University in 1906. Following graduation he was employed by the Cutler-Hammer company in the engineering department at Milwaukee, and except for a few months with the Bridgewater Woolen Mills Company, Bridgewater, Vt., in 1910, was associated with that organization continuously until his death. From 1907 to 1910 he was sales engineer for the company's Pittsburgh office, and from 1910 to 1912 special sales engineer at Milwaukee. During 1912 he was district manager of the Chicago office, and in 1913 he was made eastern district manager, with headquarters in New York. He returned to Milwaukee in 1917 as sales manager and held that position until 1924, when he was made head of the development department. Since 1930 he had been a director, vice-president in charge of engineering, and secretary, with headquarters at Milwaukee.

Charles Messick (A'03, M'13) engineer and patent attorney, New York, N. Y., died at Brentwood, N. Y., May 25, 1939. He was born in New York, N. Y., January 27, 1879, and studied at Brooklyn Polytechnic Institute. His first electrical work was with the New York Electric Vehicle Transportation Company, after which he was employed by the Riker Electric Vehicle Company, and by the Bates Manufacturing Company, both of New York. In 1901 he was employed by the United Telpherage Company, New York, as superintendent of construction and erection, and later became a selling engineer for the Chicago district. He later set up his own office in New York as electrical engineer and patent attorney, and was chief engineer for the Electrical Conveying Machinery Company. During the World War he was a lieutenant in the United States Navy, passing on patents for the Naval Consulting Board. Since the war he had continued practice as a patent attorney in New York.

John Theodore Mountain (A'04, M'13, F'20) retired, died April 16, 1939, in Glencoe, Ill. Born November 28, 1878, at Chicago, Ill., he received the degree of bachelor of science in electrical engineering from the University of Michigan in 1899. From that year until his retirement in 1935, he was associated with the Chicago Edison Company and its successor the Commonwealth Edison Company, first in the construction department, then for two years in the statistical department. His next position was apprentice substation operator. In 1904 he became a load dispatcher, and in 1906 chief load dispatcher. In 1910 he was made assistant to the chief operating engineer, a position which he held until 1935. At retirement, he was assistant service manager. He was a member of the Western Society of Engineers.

Charles Henry Kramer (A'20, M'36) chief power supervisor, Cincinnati Gas and Electric Company, Cincinnati, Ohio, died February 28, 1939. He was born May 7, 1882, in Cincinnati, and studied at the Ohio Mechanics Institute there. After being employed as switchboard operator and electrician by the South Covington and Cincinnati Street Railway Company he was transferred to the Union Gas and Electric Company as switchboard operator in 1913. He was appointed electrical foreman in 1916, and in 1920 became chief load dispatcher. He became chief power supervisor of the Union Gas and Electric Company in 1932 and when the company consolidated with Cincinnati Gas and Electric Company in 1936 continued in that position with the latter organization.

Elbert N. Renshaw (A'18) engineer in charge of the construction program of the American Telephone and Telegraph Company, Ltd., died in New York, N. Y., May 16, 1939. He was born in Brooklyn, N. Y., April 22, 1879, and took courses in electrical work from the YMCA and by correspondence. In 1893 he was employed by the American Telephone and Telegraph Company and had been engaged in engineering activities for the company ever since, working in plant extension, building and equipment, and construction program departments. At the time of his death he had charge of the general construction program for the company's entire system.

James Howe Finley, Jr. (A'27) supervisor of personnel methods, New York Telephone Company, Albany, died at Syracuse, N. Y., March 10, 1939. Born in Somerville Mass., September 13, 1903, he received the degrees of bachelor of science and master of science from Massachusetts Institute of Technology. From 1923 to 1926 he did cooperative work with the General Electric Company, and in 1926 he became an engineer for the Arkansas Light and Power Company, Little Rock. He was later employed by the International Telephone and Telegraph Company at Havana, Cuba, and then became associated with the New York Telephone Company at Albany, first as transmission engineer and later as supervisor of personnel methods.

Ralph Lawbaugh Belshe (A'35) engineer, Petroleum Rectifying Company of California, Los Angeles, died May 24, 1939. He was born September 21, 1905 at Eldon, Mo., and received the degree of bachelor of science in electrical engineering from Washington University in 1928. From 1928 to 1931 he was employed in electrical and physical research on petroleum emulsions by the Tretolite Company, Webster Groves, Mo. He was transferred to the Petroleum Rectifying Company of California as research engineer on its affiliation with the Tretolite Company, and at the time of his death was engaged in layout and operation of electrical dehydrating equipment. He was a member of Sigma Xi.

Membership

Recommended for Transfer

The board of examiners, at its meeting on June 15, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Borch, Frederik, assistant electrical engineer, Cleveland Electric Illuminating Company, Cleveland, Ohio.
Edwards, E. J., manager, plant engineering department, General Electric Company, Cleveland, Ohio.
Fick, C. W., district engineer, General Electric Company, Cleveland, Ohio.
Harrington, C. A., member of electrical engineering staff, Cleveland Electric Illuminating Company, Cleveland, Ohio.
Hertz, S. S., executive director, Copper Wire Engineering Association, Washington, D. C.
Marti, O. K., engineer-in-charge, rectifier equipment, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Shoemaker, G. T., president, The United Light and Power Service Company, Chicago, Ill.
Weinbach, M. P., professor of electrical engineering, University of Missouri, Columbia.

8 to Grade of Fellow

To Grade of Member

Berkey, W. E., research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Blackstone, W. S., design engineer, The McKay Machine Company, Youngstown, Ohio.
Burgwin, S. L., research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Chapman, H. N., chief engineer, Woodward and Tiernan Printing Company, St. Louis, Mo.
Croft, W. H., design engineer, Central Arizona Light and Power Company, Phoenix, Ariz.
Denault, C. L., section engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Dyer, G. A., outside plant engineer, Southwestern Bell Telephone Company, Dallas, Tex.
Fitzgerald, A. E., instructor in electrical engineering, Massachusetts Institute of Technology, Cambridge.
Franklin, R. F., electrical engineer, General Electric Company, Schenectady, N. Y.
Friend, A. W., assistant professor of physics, West Virginia University, Morgantown.
Hanna, C. R., electromechanics division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Hayman, W. C., engineer, cable department, General Electric Company, Schenectady, N. Y.
Himebrook, F. S., electrical engineer, The General Industries, Inc., Elyria, Ohio.
Holman, H. R., engineer, National Carbon Company, Inc., Cleveland, Ohio.
Lewis, W. A., director of electrical engineering, Cornell University, Ithaca, N. Y.
Morris, R. C., operating superintendent, Union Electric Company of Missouri, St. Louis.
Nelson, L. V., power supervisor, Union Electric Company of Missouri, St. Louis.
Oplinger, K. A., research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Outt, J. R., electrical engineer, General Electric Company, Fort Wayne, Ind.
Peterson, G. H., telephone engineer, Bell Telephone Laboratories, Inc., New York, N. Y.
Ranson, L. E., development engineer, Clark Controller Company, Cleveland, Ohio.
Rorke, C. B., assistant electrical engineer, Canadian and General Finance Company, Toronto, Ont., Can.
Rose, J. J., assistant engineer, New York and Queens Electric Light and Power Company, Flushing, N. Y.
Schlemmer, O. C., plant supervisor, Cincinnati and Suburban Bell Telephone Company, Cincinnati, Ohio.
Sparks, V. F., designing engineer, Ohio Brass Company, Mansfield.
Strom, A. P., research engineer, Westinghouse Electric and Manufacturing Company, Trafford, Pa.
Toepfer, A. H., research engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Vernon, H. H., industrial department, General Electric Company, Schenectady, N. Y.
Walters, T. R., section head, General Electric Company, Pittsfield, Mass.
Winograd, H., electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

30 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1939, or September 30, 1939, if the applicant resides outside of the United States or Canada:

United States and Canada

1. NORTH EASTERN

Cariapa, C., Jr., International General Electric Company, Schenectady, N. Y.
Clark, E. S., Springfield Trade School, Springfield Mass.
Frankl, F., Freydberg Bros., Inc., Stamford, Conn.
Hilding, J. H., Electric Boat Company, Groton, Conn.

2. MIDDLE EASTERN

Delfs, J. M., 220 High Street, Canfield, Ohio.
Dowd, I. F., Toledo Industrial Rubber Company, Toledo, Ohio.
McDaniel, R. E., General Electric Company, Philadelphia, Pa.
Patton, G. J. K., Bell Telephone Company of Pennsylvania, Philadelphia.
Penzickes, C., Philadelphia Navy Yard, Philadelphia, Pa.
Reiff, L. S., Metropolitan Edison Company, Reading, Pa.
Shombert, G., Jr., Allis-Chalmers Manufacturing Company, Pittsburgh, Pa.
Strosser, R. J., Cleveland Electric Illuminating Company, Cleveland, Ohio.
Venegas, C., 404 East Ninth Street, Chester, Pa.

3. NEW YORK CITY (TERRITORY OF THE NEW YORK SECTION)

Gorin, E., 953—47th Street, Brooklyn, N. Y.
Quist, A. H., Jr., Radio Engineering Laboratories, Long Island City, N. Y.
Short, A. L., United States Electric Motors, Brooklyn, N. Y.
Whiting, M. T., Public Service Electric and Gas Company, Hackensack, N. J.

4. SOUTHERN

Abbott, L., Tennessee Valley Authority, Knoxville, Tenn.
Dunagan, G. C., Tennessee Valley Authority, Guntersville Dam, Ala.
Leppert, J. H., Tennessee Valley Authority, Guntersville Dam, Ala.
McCoy, J. H., Tennessee Valley Authority, Wilson Dam, Ala.
O'Brien, F. J., Tennessee Valley Authority, Knoxville, Tenn.
Olivier, L. J., Louisiana Power and Light Company, New Orleans.
Porter, J. O., Columbia Military Academy, Columbia, Tenn.

5. GREAT LAKES

Boesenberg, H. H., Public Service Company of Northern Illinois, Maywood, Ill.
Owen, C. B., Aluminum Company of America, Chicago, Ill.
Patterson J. D., Commonwealth Edison Company, Chicago, Ill.
Peirce, G. R., University of Illinois, Urbana.

6. NORTH CENTRAL

Torvick, E. B., American Telephone and Telegraph Company, Denver, Colo.

7. SOUTH WEST

Brown, H. A., New Mexico State College of Agricultural & Mechanical Arts, State College, N. Mex.
Loutzenheiser, H. C., Raymond H. Reed Engineering Company, Abilene, Kans.
Sargi, G. (Member), Stone and Webster Engineering Corporation, Beaumont, Tex.
Stalnecker, F. I., El Paso Electric Company, El Paso, Tex.

8. PACIFIC

Beeman, K. C., Phelps Dodge Copper Products Corporation, Los Angeles, Calif.
Cox, J. L., Nevada-California Electric Corporation, Bishop, Calif.
Marshall, R. E., Nevada-California Electric Corporation, El Centro, Calif.
Moran, G. E., Southern California Edison Company, Ltd., Alhambra, Calif.
Nevin, P. P., Southern California Edison Company, Ltd., Alhambra, Calif.
Poniatoff, A. M., Pacific Gas and Electric Company, San Francisco, Calif.

9. NORTH WEST

Sisk, W. R., Otis Elevator Company, Spokane, Wash.
Stalker, W. N., Otis Elevator Company, Spokane, Wash.
Wheeler, L. E., City of Seattle, Wash.

10. CANADA

Biskeborn, H. W. (Member), Phillips Electrical Works, Ltd., Brockville, Ont.
Connors, L. McC., Canadian General Electric Company, Toronto, Ont.
Rose, C. J., International Metal Industries, Toronto, Ont.

Total, United States and Canada—45

Elsewhere

Ananthanarayanan, C. N., Government Electricity Department, Coimbatore, Madras, India.
Bedil, S. D., Punjab Public Works Department, Lahore, Punjab, India.
Nagabhushanam, K., Power and Light, Chikmaglur, Mysore State, India.
Setty, K. S. (Member), C. N. T. Institute, Vepery, Madras, India.
Watton, B., British Thomson-Houston Company, Ltd., Willesden, London, England.

Total, elsewhere—5

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Barnes, Maurice T., Coan, Va.
Coleman, Irwin M., 581 Academy St., New York, N. Y.
Ebert, Kenneth W., 776 N. Cass St., Milwaukee, Wis.
Ember, Theodore, 4011 Springdale Ave., Baltimore, Md.
Fies, John, Dallas Power & Light Co., Dallas, Texas
Garvey, Fred A., Brownsville, Tenn.
Hall, John R., c/o Patrick Tyrrell Drilling Co., Cotton Exchange Bldg., Houston, Texas
Hicks, William A., 1862 Central Ave., Augusta, Ga.
James, George Hazard, Jr., 7 Meikle Ave., Newport, R. I.
Johnson, James Steven, 213 Buckingham St., Hartford, Conn.
Lewis, Rodney C., 310 Garland Ave., Takoma Park, Md.
McCarthy, C. C., c/o Westinghouse Electric and Manufacturing Co., 814 Ellicott Square, Buffalo, N. Y.
McWhorter, W. Allen, Jr., 4540 Lake Park Ave., Chicago, Ill.
Modisette, M. H., 4514—10th St., N. E., Seattle, Wash.
Ratajczak, Frank X., 1635 Delaware Ave., Wyomissing, Pa.
Strauss, Walter A., 39 West 60th St., New York, N. Y.
Taylor, C. Max, 1801 Monroe St., Endicott, N. Y.
Tolman, Clarence M., 310 N. Aurora St., Ithaca, N. Y.

18 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Electrical engineers may be interested in the following new books, which are among those recently received at the Engineering Societies Library, New York, N. Y. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the preface of the book in question.

HIGH-FREQUENCY ALTERNATING CURRENTS. By K. McIlwain and J. G. Brainerd. Second edition. New York, John Wiley and Sons, 1939. 550 pages, illustrated, 9 by 6 inches, cloth, $6.00. Presents the mathematical analysis of the operation of electric circuits at high frequencies as a course for advanced electrical engineering students, to be accompanied by practical laboratory work. Topics include thermionic vacuum tubes, electric-wave filters and transmission lines, amplification, modulation, detection, etc. The co-ordination of quantities and units in electromechanical-acoustic systems is considered in the final chapter. Chapter bibliographies.

ELECTRIC CIRCUITS AND WAVE FILTERS. By A. T. Starr. Second edition. New York and Chicago, Pitman Publishing Corporation, 1938. 476 pages, illustrated, 9 by 6 inches, cloth, $6.00. The opening chapters present fundamental mathematical processes, alternating-current theory, and electric circuit theory. Design information is given for resistances, capacitors, and coils, including transformers, preceding a discussion of wave filters. Separate chapters are devoted to low-pass, high-pass, and band-pass filters. Attention is also given to acoustic analogies, electro-acoustics, and transients in networks. Long appendices summarize the information about filters, and the characteristics of band-pass filters are expressed in a nomogram.

EINFÜHRUNG IN DIE SIEBSCHALTUNGSTHEORIE DER ELEKTRISCHEN NACHRICHTENTECHNIK. By R. Feldtkeller. Leipzig, S. Hirzel, 1939. 174 pages, diagrams, etc., 9 by 6 inches, paper, 10.80 rm.; bound, 12 rm. Deals with the theory of filters in communication work. The various types are considered, with mathematical analyses and explanatory diagrams. Two chapters are devoted to the problems of balancing and damping.

THE DECLINE OF MECHANISM IN MODERN PHYSICS. By A. d'Abro. New York, D. Van Nostrand, 1939. 982 pages, diagrams, etc., 9 by 6 inches, cloth, $10.00. Reviews the historical development of physical theories from their beginnings to the modern quantum theory. Particular stress is laid on Heisenberg's "principle of uncertainty," and on the reasons which compelled physicists to abandon classical interpretations. The three parts of the book deal, respectively, with the fundamentals of natural philosophy, with a review of mathematics and the more important classical physical theories, and with a discussion of the various quantum theories and the doctrine of causality.

CITY PLANNING, WHY AND HOW. By H. M. Lewis. New York and Toronto, Longmans, Green and Company, 1939. 257 pages, maps, etc., 9 by 6 inches, cloth, $2.50. Discusses the need and advantages of planning for future growth or change in a municipality, and indicates the part the average citizen can play in this development.

APPLIED PHOTOGRAMMETRY. By R. O. Anderson. Second edition. Ann Arbor, Mich., Edwards Brothers, 1939. 190 pages, illustrated, 8 by 5 inches, cloth, $2.50 (10 copies or more, $2.00 per copy). As in the previous edition, methods for determining the correct scales of aerial photographs are given, together with an analytical radial-line method of control, which takes into account both relief and tilt. In the revision, the theory has been extended and a chapter given on the graphical-ray method of control. The present volume constitutes a textbook as well as a reference work for the application of aerial photography to various types of surveys.

THE SUPERHEATER IN MODERN POWER PLANT. By D. W. Rudorff. London, Sir Isaac Pitman and Sons; New York, Pitman Publishing Corporation, 1938. 293 pages, illustrated, 9 by 6 inches, cloth, $6.00. Aims primarily to present actual ways and means of superheating saturated steam. Most of the chapters contain descriptive material on various types of superheaters. There are also chapters on superheater computation and regulation and on the mechanical design and operation of superheaters. Tables on superheated steam are appended. The book is based on a series of articles which appeared in *The Engineering and Boiler House Review*.

Engineering Societies Library

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Transactions

Papers and Discussions Comprising Pages 307–70 of the 1939 Volume

Low-Gas-Pressure Cable

G. B. SHANKLIN
MEMBER AIEE

DURING the past several years the company with which the writer is associated has been conducting an extensive research and engineering study of the possibilities of high-voltage cable utilizing gas as a pressure medium. The purpose has been to develop a practical cable system of this type and determine its best field of usefulness from an engineering and economic standpoint. The results of this work to date will be outlined in the present paper.

Since the need of high-voltage underground transmission arose some 40 years ago there has been and will always be a continual effort to obtain better and more economical designs of cable systems. Out of these years of experience certain principles and trends have been established. Of all the different insulating materials available, oil- or compound-impregnated paper is recognized as the best and most economical for cable rated 22 kv and above. It is also widely used at lower voltages. All of the various high-voltage cable systems that have been generally used, or subjected to full-size experimental field trial, in recent years have utilized impregnated paper as the basic insulation.

The cable systems mentioned utilize impregnated paper in different ways to accomplish certain desired results, but all of them follow, or try to follow, the same fundamental principles. These are:

(*a*). Use materials that are chemically and physically stable and of low dielectric loss and high dielectric strength.

(*b*). Eliminate all traces of impurities initially and prevent entrance of such impurities during shipment, field installation, and service.

(*c*). Prevent progressive ionization deterioration at all times.

Experience has demonstrated that the first step in accomplishing these results involves vacuum drying and impregnation under pressure after fabrication of the cable. Uniformly perfect initial impregnation is the only known method of obtaining full control of cable quality and economically meeting the requirements outlined. Incomplete initial impregnation in the factory leads to loss of uniformity, with weak spots along the cable length. Pretreatment of paper tape also makes the complete removal of impurities a questionable process.

The two high-voltage cable systems so far used to an extent that classifies them as standard are the ordinary "solid type" cable and the "oil filled" cable. The essential features of these two cable systems will be briefly outlined for purposes of leading up to a logical field of usefulness for the low-gas-pressure cable system that will be described.

Solid-Type Cable

This is the original type of high-voltage cable, used for 40 years or more. About 20 years ago a growing demand for higher operating voltages and reduced costs led to marked improvement in insulation quality and increase in working voltage stress (decrease in insulation thickness). Within recent years uniformity and practically perfect initial impregnation have been obtained by improvement of the impregnation treatment and the use of nonsolidifying impregnating compounds of lower viscosity.[1,2] Present-day insulation thicknesses represent an average working voltage stress of from 42 to 58 volts per mil.

Solid-type cable has now about reached its ultimate development. Present limitations are inherently physical. Complete impregnation has improved the insulation but has increased the physical problem. Today, we are faced with the following inherent difficulties:

(*a*). No method of controlling relatively wide pressure fluctuations due to temperature changes in service. Compound expansion during heating increases pressure and this puts an undue stress burden on the lead sheath, causing permanent stretching, fatigue splits, and other sources of leakage.

(*b*). During periods of cooling negative pressures (vacuum) develop. Air and moisture are drawn into the system through any leaks that exist.

(*c*). Stretching of sheath and migration of the nonsolidifying compound lead to void formation. During periods of negative pressure cumulative ionization damage is liable to occur.

Oil-Filled Cable

The success of oil-filled cable is too well known to require repetition here. It completely overcomes the inherent difficulties of solid-type cable just discussed.[3] Ionization is eliminated entirely and predetermined safe working stresses on the lead sheath are under control at all times. Positive oil pressure is maintained, preventing entrance of impurities at points of accidental leakage. Low working oil pressure (1 to 30 pounds, depending upon contour) greatly simplifies design, installation, and maintenance. This low pressure allows ordinary lead sheath finish up to 15 pounds and a simple reinforced sheath finish from 15 to 30 pounds. The cable can be installed anywhere that solid-type cable can, drawn into ducts, buried, etc.

Today, the average working voltage stress in oil-filled cable is from 80 to 143 volts per mil, depending upon voltage rating. This is more than twice that of solid type, and the ultimate reduction in insulation thickness has not yet been reached. It will depend upon required impulse strength to resist lightning and switching surges. Experience has shown that normal 60-cycle working stress is not a limiting factor in determining minimum insulation thickness. The rea-

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A number of engineers associated with the author, too numerous to list in full, have contributed to this development. The writer particularly wishes to acknowledge the valuable help of J. A. Scott and J. B. Felter, who carried out the laboratory tests, S. J. Garahan, W. C. Hayman, C. A. Piercy, E. L. Crandall, F. W. Engster, F. H. Buller, L. L. Phillips, V. A. Sheals, and T. C. Aitchison, all of whom gave generously of their support and encouragement. The fine spirit of co-operation shown by the Consolidated Edison and Yonkers Electric Light and Power companies is gratefully acknowledged.

1. For all numbered references, see list at end of paper.

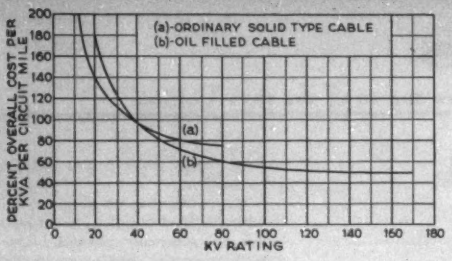

Figure 1. Unit overall installed costs in underground ducts

son for this is that even one or two pounds positive oil pressure in the feed channels is sufficient to prevent void formation in a properly designed cable.[3] Accordingly, the oil-filled cable system is inherently a low-pressure system. There is no need of complicating matters by increasing oil pressure above that actually required by the contour and length of section to be fed. Technically, the standard low-pressure oil-filled cable system is correct and superior to all high-voltage cable systems so far devised. It is only from an economic standpoint that it leaves room for improvement.

Figure 1 gives comparative over-all installed unit costs for oil-filled and solid-type cable systems in underground ducts as a function of voltage rating. At any given voltage the costs will vary with load but the curves in figure 1 are representative averages for the most economical conductor sizes. It will be noted that the unit cost of oil filled increases more rapidly than that of solid cable systems with decrease in voltage rating. At 38 kv the costs are about the same. Below 38 kv solid-type cable is more economical in average cases.

The reason for this is that the reservoirs, stop joints, and other accessories used with oil-filled cable are relatively more costly than those used with solid cable. Total accessory cost decreases much more slowly than total cable cost with decrease in voltage rating, conductor sizes remaining the same. Also, total cable cost for oil filled, while considerably less at higher voltages, due to smaller diameter and lesser material, decreases more slowly than solid-cable cost as voltage rating decreases. Figure 1 explains why solid-type cable is still more commonly used below 38-kv rating.

Gas-Pressure Cable

Experience with oil-filled cable has demonstrated in a striking way the benefits of maintaining positive pressure during shipment, installation, and service. In attempting to develop newer and better cable systems these basic principles should be followed.

Maintenance of pressure requires a pressure medium. There are only two well recognized pressure mediums, liquid (oil) and gas. The development field utilizing oil as a pressure medium is now covered and is best exemplified by the standard low-pressure oil-filled cable system. The use of gas as a pressure medium leaves a more versatile field of exploration. In the way of simplicity, at least, it is attractive. There are no hydrostatic head pressures to deal with and the accessory designs are simple, at least for low pressure systems. Installation and maintenance are also simplified.

Soon after entering this field of development we concluded that a dry, inert gas in direct contact with and saturating the impregnated-paper insulation gave the best assurance of maintaining pressure through the whole cable cross section with minimum time lag during temperature and pressure variations. It was further concluded that longitudinal gas feed channels in the cable would facilitate control of uniform gas pressure along the cable length in service; in fact, were necessary fully to accomplish this purpose. The feed channels fulfill another important function in providing surplus gas at any point of accidental leakage. Without longitudinal feed channels that will readily convey surplus gas, pressure would be rapidly lost at such leakage points and cause failure.

The tests and development work leading up to present conclusions will be described in detail but first it will be explained why, at least for the time being, we are concentrating on low-gas-pressure systems of moderate voltage rating, and consider this the most promising field of development.

Figure 2 shows the voltage at which ionization starts as a function of gas pressure. The curve is a representative average of all the tests on single- and three-conductor gas-pressure cable that will be described, using nitrogen gas as a pressure medium. The measurements were made after load-cycle drainage of compound.

The voltage at which ionization started in these gas-filled voids is shown in figure 2. The drooping shape of the curve is significant and important. Fifteen pounds pressure comes within safe working limits for ordinary single lead sheath. The steepest part of the curve in figure 2, and a good part of the gain in ionization voltage, occurs in this relatively low pressure range. The ionization voltage at 15 pounds pressure is 80 volts per mil, which is the lower limit of working stress for oil-filled cable.

Forty pounds pressure comes within safe working limits for ordinary double reinforced sheath, as proved by some years of experience with oil-filled cable. This is the next steepest part of the curve and the ionization voltage at 40 pounds pressure is 112 volts per mil. This gain in voltage stress is not obtained, however, without increased cost. For average cable sizes double reinforced sheath increases cable cost from 10 to 15 per cent as compared with single sheath. This can be justified only when balanced by an equivalent saving in insulation cost (reduced thickness). Actually, it is not completely justified then, because years of experience with oil-filled cable has established the fact that single sheath at 15 pounds pressure has given a better service record than double reinforced sheath at 40 pounds pressure.

As a first stage in the practical development of gas pressure cable it is our intention to establish the ultimate safe operating voltage for cable with single lead sheath and 15 pounds pressure and resort to reinforced sheath with 30 to 40 pounds pressure only for higher voltages. At just what voltage this can be justified will depend upon field experience. We do not yet know ultimate safe working voltage stresses. At the present writing, and judging from laboratory tests alone, single-sheath cable at 10 to 15 pounds pressure will have an ultimate working voltage stress (average) of about 75 volts per mil, and reinforced sheath cable at 30 to 40 pounds pressure about 100 volts per mil. If this is proved by field experience then, economically, single-sheath cable will have a maximum operating voltage of about 40 kv. This voltage range happens to fill the economic gap caused by the relatively high cost of oil-filled cable below 38 kv as shown in figure 1. We believe that the greatest field of usefulness for gas-pressure cable is in filling this gap.

High-Gas-Pressure Cable

Referring again to figure 2, the ionization voltage at 200 pounds pressure is 162 volts per mil. This is by no means a sufficient gain in voltage stress, as compared with the 40-pound results, to warrant a fivefold increase in gas pressure, with the rather serious complications it introduces.

With few exceptions, important high-voltage cable lines in this country are installed in duct systems, mostly under paved city streets. Any cable used must be flexible so that it can be drawn from shipping reels into these ducts and trained around the manhole walls to form expansion bends and facilitate racking of joints. Gas-pressure cable with single sheath at 15 pounds and ordinary double-reinforced sheath at 40 pounds is readily adapted to these requirements. We are only concerned with the radial stresses on the sheath. Longitudinal stresses are of no great importance. Ordinary lead plumbing wipes are used and there is no tendency for the cable to move or "whip" due to excessive internal pressure. All of this has been demonstrated by experience with oil-filled cable.

At 200 pounds pressure a very elaborate type of sheath reinforcement would have to be used, taking care of both radial and longitudinal strains. All plumbing wipes would also have to be reinforced radially and longitudinally. Curvature in the duct run and expansion bends in the manholes would have to be dispensed with or the cable given rigid support with sufficient bearing surface to avoid crushing.

This special high-pressure reinforcement would add at least 20 to 25 per cent to cable cost as compared with ordinary single-sheath low-pressure oil-filled cable. This is, without question, more than the difference in cost of oil-filled cable accessories and high-pressure gas cable accessories.

On the above basis it is reasonable to conclude that the over-all installed cost of a 200-pound gas-pressure system for 138-kv service in underground ducts would exceed the cost of an equivalent low-pressure oil-filled system. In view of the experimental nature of reinforced sheath operation at 200 pounds pressure and the difficulties of maintenance and repair work, we feel it advisable first to determine the practical possibilities of low-pressure gas systems for moderate voltage use and leave the supervoltage field to oil-filled cable for a while longer.

Laboratory Tests

General Conditions

The series of laboratory tests on gas-pressure cable, started about five years ago, have included different types of impregnating compound, different densities of paper tape, various gases, and variations in method of constructing and treating the cable. Both single-conductor and three-conductor cable have been tested.

Single-Conductor Cable

All single-conductor cable used in these tests had either 350,000-circular-mil or 400,000-circular-mil stranded conductor with one-half-inch hollow core. The insulation was 0.300-inch impregnated paper tape, and over this a one-eighth-inch lead sheath. The cable was given a very complete vacuum drying and impregnation treatment and the test lengths (50 feet) were end sealed and sent to the laboratory without drainage, other than blowing the core free of compound and filling with gas to ten pounds pressure.

In the laboratory the lengths were drawn into 2.0-inch steel pipe and special high-pressure porcelain test terminals assembled at each end. The hollow core of the cable and the space in the steel pipe were interconnected through the terminals. Both were evacuated and filled with gas to required pressure. An insulated current transformer furnished load heating current to the conductor. The lengths were subjected to 60-degree-centigrade load cycles and simultaneous gas-pressure cycles from atmospheric to 100 and 200 pounds for a number of days until a capillary balance was reached and drainage of compound from the core ceased. Power factor versus voltage curves were then measured in pressure steps from atmospheric to 200 pounds at room temperature and 60 degrees centigrade. After this the lengths were subjected to load-cycle overvoltage endurance with periodic measurement of power factor and ionization. Two to three complete load cycles per day were applied from room temperature (25 to 30 degrees centigrade) to 60 and 65 degrees centigrade.

Three-Conductor Cable

The three-conductor test lengths were 75 feet long with 350,000-circular-mil sector conductors and 0.200-inch paper tape, shielded. All filler material was omitted from filler spaces, which acted as gas feed channels. The first test length had no support in the filler spaces. Remaining lengths had steel spiral support in the filler spaces similar to that used with oil-filled cable. The insulated and shielded conductors were cabled together with a metal-tape binder and a one-eighth-inch lead sheath was applied after treatment.

After vacuum drying and impregnation in the usual manner the lengths were left in the treating tank and drained of surplus compound in an atmosphere of the same gas later used as a pressure medium on test. Drainage was at 60 to 70 degrees centigrade for a considerable period of time. Afterward the lengths were leaded in an atmosphere of the same gas, end sealed, and sent to the laboratory under ten pounds pressure.

The lengths were subjected to short-time ionization tests up to 30 pounds pressure and long-time load-cycle overvoltage tests up to 15 pounds pressure. It was consequently not necessary to install them in steel pipe and all tests were made with bare lead sheath exposed. Ordinary porcelain pothead terminals were assembled in inverted position to facilitate drainage of compound from the cable, which, in effect, was arranged as an inverted U. The three conductors were connected in series for application of load-cycle current. In all other respects test procedure was as outlined for single-conductor cable, except that the load cycles were carried to 70 and 80 degrees centigrade.

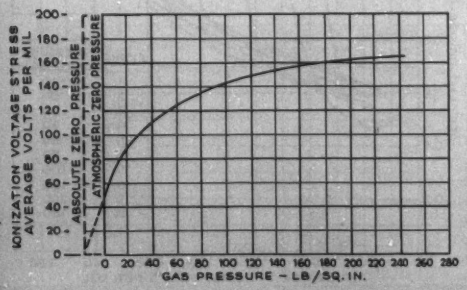

Figure 2. Voltage stress on solid insulation at which ionization starts as a function of gas pressure in voids of gas-pressure cable

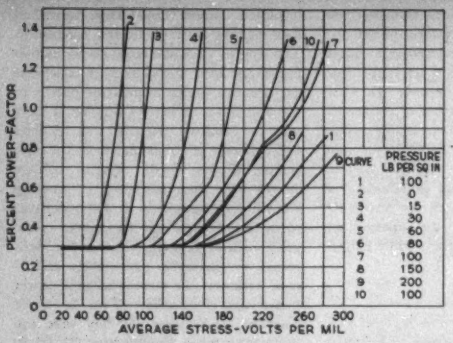

Figure 3. Test length number 5—ionization curves after prolonged load-cycle bleeding—measured at 25 degrees centigrade

Test Length Number 1. Single conductor, impregnated with relatively thin oil similar to that used in oil-filled cable and having a viscosity of 37 Sayholt at 100 degrees centigrade. Pressure medium, CO_2 gas.

Due to the thin oil and the large volumetric absorption of CO_2, the bleeding under load and pressure cycles was excessive, approximately 33 per cent of the original oil in the paper being expelled. Ionization was also poor, beginning at about 35 volts per mil atmospheric pressure. The length was submitted to a 65-degree-centigrade load-cycle endurance run at 300 volts per mil and 200 pounds pressure. Failure occurred in 22 hours.

Test Length Number 2. All conditions similar to those for length number 1 with the exception that the cable was impregnated with a heavier all-mineral-oil compound similar to that used in solid-type cable and having a viscosity of 95 Saybolt at 100 degrees centigrade

The expulsion of compound was improved, being about 25 per cent, and ionization was also improved. In spite of this, failure occurred in $7\frac{1}{2}$ hours on load-cycle endurance at 300 volts per mil, 200 pounds pressure.

Test Length Number 3. This length was a duplicate of length number 1, the only difference being that nitrogen gas was used instead of carbon dioxide. On load-cycle endurance at 300 volts per mil, 200 pounds pressure, failure occurred in 80 hours. This was an improvement compared with length number 1 but the thin compound still bled too freely.

Test Length Number 4. This length was similar to length number 2 with the exception that nitrogen gas was substituted for carbon dioxide. This gave decided improvement in both compound expulsion and ionization. On the same 65-degree-centigrade load-cycle endurance as length number 3 failure occurred after 801 hours.

Test Length Number 5. Exactly similar to length number 4 and all test conditions the same with the exception that the 60-degree-centigrade load-cycle endurance run was made at low pressure (15 and 10 pounds) and at voltage stresses just above the ionization point (80 and 100 volts per mil). The load-cycle endurance run was continued for a long period of time, more than two years.

Figure 3 gives 25-degree-centigrade ionization curves at different pressures after the length had been subjected to a large number of load cycles and alternate applications of vacuum and 200 pounds nitrogen pressure before the endurance run. Compound expulsion had practically ceased by the time figure 3 was obtained. The corresponding 60-degree-centigrade power factor curves are given in figure 4. It will be noted that ionization starts at a higher voltage at 60 degrees centigrade, as would be expected. It should also be noted that while the solid loss power factor at 25 degrees centigrade is practically horizontal before ionization starts the corresponding 60-degree-centigrade curves in figure 4 show a pronounced up slope of solid loss power factor as voltage increases. This is inherent in this type of cable and, since it obscures true ionization loss, only the room temperature results will be used as an indication of ionization in the load-cycle endurance charts that will be presented for the different test lengths. As a matter of fact, even the room-temperature measurements show this positive coefficient of solid loss power factor in most of the test lengths and this must be allowed for.

Figure 5 gives a chart of the 60-degree-centigrade load-cycle endurance run, 105 days at 15 pounds and 80 volts per mil, 255 days at 10 pounds and 80 volts per mil, and 470 days at 10 pounds and 100 volts per mil. The total length of the load-cycle voltage test was 830 days. At the end of that time the cable had stabilized so test was discontinued and the length carefully dissected for study of *X* wax.

Referring to figure 5, after the first 9 days at 15 pounds, 80 volts per mil, ionization practically disappeared and remained negligible until 100 volts per mil was applied at the end of 360 days. At the beginning ionization was more pronounced, as would be expected, but again decreased and practically disappeared after an additional 300 days. The 60-degree solid loss gradually increased from 1.0 per cent to approximately 2.0 per cent. It then decreased

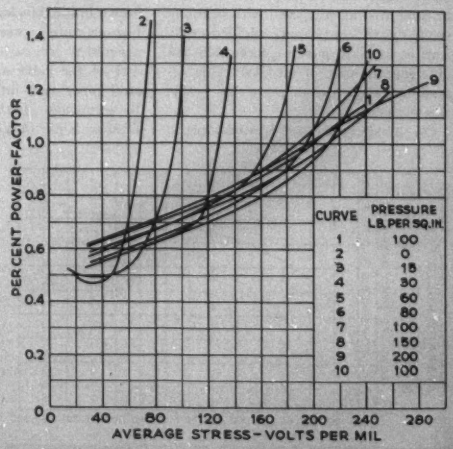

Figure 4. Test length number 5—ionization curves at same time and in same order as those in figure 3—measured at 60 degrees centigrade

and at the end of the run (830 days) had returned to the initial 1.0 per cent value. The "saw tooth" fluctuations in the power factor plots are typical of all tests made and are due to fluctuations in copper temperature. It is difficult to hold exactly uniform copper temperature during these measurements. It will be noted that the power factor and temperature fluctuations follow each other closely, particularly at 60 degrees centigrade where power factor is more sensitive to temperature changes.

Wax distribution was uniform throughout the insulation thickness and occurred only in the butt spaces between paper tape edges. There were no signs of tree-design overstressing or cumulative ionization trouble, only the limited *X* wax formation in the butt spaces, previously described.

Test Length Number 6. Three-conductor cable, impregnated with same compound as length number 5 and also using nitrogen as a pressure medium.

Power factor curves (24 degrees) after stabilized load-cycle bleeding are given in figure 6. The 24-degree-centigrade solid loss power factor has a distinct upward slope with increased voltage stress. This not only obscures the starting point of ionization but must be allowed for in interpreting the room temperature ionization measurements on the load-cycle endurance run chart given in figure 7.

This chart shows that length number 6 was subjected to 80-degree-centigrade load-cycle endurance for 147 days at 75 volts per mil and 10 pounds pressure. Ionization was noticeable at the start but had practically disappeared at the end of 70 days (making due allowance for the upward slope of solid loss in figure 6). At the end of 147 days the cable was stabilized, so voltage stress was increased to 85 volts per mil. Again ionization appeared and gradually ceased after 49 days further testing. After that the cable was completely stable for a total time of 400 days. The same characteristic self-healing and self-extinguishing effect of ionization found with length number 5 is present in length number 6 after each endurance voltage step. The high-temperature solid loss also behaves in the same way, increasing some and then gradually decreasing to its initial value.

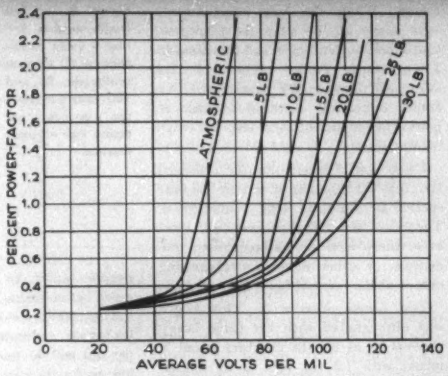

Figure 6. Test length number 6—ionization curves after load - cycle bleeding—measured at 24 degrees centigrade

After 400 days the test was discontinued and the cable subjected to vacuum treatment to remove all nitrogen gas. It was then filled with Freon gas to determine whether the high dielectric strength of this gas (more than twice that of nitrogen) would prove beneficial. Power-factor curves at different pressures showed that Freon increased ionization voltage approximately 50 per cent.

The 80-degree-centigrade load-cycle endurance run was then continued at 85 volts per mil, 10 pounds Freon gas pressure. Solid loss immediately began to increase and after 24 days the test was discontinued. At that time the 80-degree-centigrade power factor had increased to 7.0 per cent, more than double its original value. We are not sure of the real cause of this increase. It may have been due to chloride impurities in the Freon or it may have been caused by dissociation of Freon from ionization discharge. We intend to study the possibilities of Freon and other high-dielectric-strength gases further. In the meantime we will use nitrogen as the best of the available common gases.

The Freon test was stopped before the cable was seriously damaged and it was then dissected for study of *X* wax formation. Again wax was found only in the butt spaces, more or less uniformly distributed through the thickness, and without other signs of overstressing.

Test Length Number 7. This three-conductor length was exactly similar to length number 6 with the one exception that two layers of manila paper tape were bound over the metal shielding tape on each insulated conductor.

The power factor versus voltage curves at different pressures were similar to those in figure 6, but the upward slope of the solid loss power factor was more pronounced and calls for a greater allowance in the load-cycle endurance chart given in figure 8. Length number 7 was subjected to an 80-degree-centigrade ten-pound load-cycle endurance test at 85 volts per mil for 400 days. It will be noted in figure 8 that ionization during this time was more pronounced than in length number 6, figure 7, and required a longer time to heal itself. At the end of 300 days ionization had practically disappeared and the 80-degree-centigrade solid loss had returned to its initial value. Test voltage was then increased to 100 volts per mil and ionization became pronounced. Both ionization and solid loss showed a tendency to gradually decrease but a stable condition was not reached. At the end of 110 days at 100 volts per mil solid loss began to in-

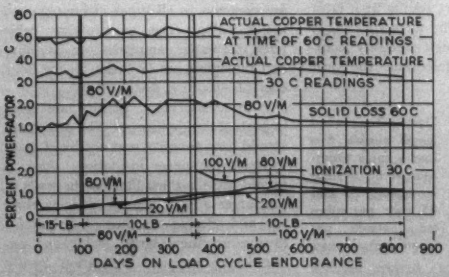

Figure 5. Test length number 5—load - cycle endurance at 80 and 100 volts per mil—15 and 10 pounds per square inch nitrogen pressure

crease. When the last measurements were made at 160 days the 80-degree-centigrade power factor had increased to 2.9 per cent. Failure occurred 7 days later (167 days, or 567 days total). No doubt there was a rapid increase in power factor during the last few days before failure.

Dissection of length number 7 showed the same distribution of wax in the butt spaces as found in length number 6. The wax was more pronounced, however, there were no carbonization, tree designs, or other signs of overstressing except at the point of failure.

Test Length Number 8. This length was impregnated with the same heavy mineral oil as lengths numbers 6 and 7, mixed with 1.5 per cent of an experimental, viscous compound to increase viscosity. The viscosity of the mixture was 350 Saybolt at 100 degrees centigrade. While the viscosity was increased there did not appear to be an equal increase in tackiness and film tension, the compound bleeding at high temperature being about the same as previously.

The 80-degree-centigrade ten-pound load-cycle endurance-run data at 85 volts per mil will be found in figure 9. The run has continued for 220 days to date and the length is still on test. As far as it has gone, the endurance run has shown about the same results as obtained with length number 6.

This length, alone, would not indicate any real benefit from increased viscosity of impregnating compound. We attribute this mostly to a lack of film tension in this particular mixture. Good film tension is, of course, necessary to hold the compound in place by capillary attraction.

Test Length Number 9. Similar to length number 8 except that the heavy oil compound contained 20 per cent rosin. The mixture had a viscosity of 200 Saybolt at 100 degrees centigrade. This mixture had more tackiness and better film tension than that in length number 8.

The rosin used was not the modern water-white type but was an older and less highly refined grade. It was desired to study the stability of this older grade before trying the newer.

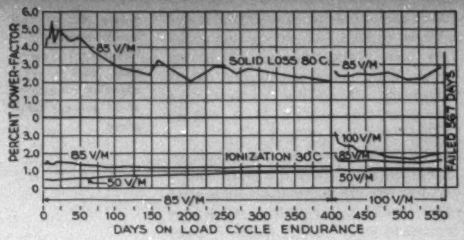

Figure 8. Test length number 7—load - cycle endurance at 80 degrees centigrade, 85 and 100 volts per mil—ten pounds per square inch nitrogen pressure

The 80-degree-centigrade ten-pound load-cycle endurance chart at 85 volts per mil will be found in figure 10. Allowing for the upward slope of the solid loss power factor the ionization from the start has been quite small and seems to confirm the opinion that an impregnating compound of high viscosity and high film tension improves ionization characteristics in gas pressure cable. The solid loss, however, began to increase rapidly after 37 days and, to date (170 days), appears to be still increasing. Test will be continued on this length.

Hot spots were found along the cable soon after the increase in dielectric loss was observed but the cable has not yet shown signs of final failure. The instability of this length is undoubtedly due to the grade of rosin used. It is recognized as lacking the stability of highly refined, water-white rosin.

Test Lengths Numbers 10 and 11. These two lengths of three-conductor cable are similar to length number 9 with following exceptions. Length number 10 has 20 per cent highly refined water-white rosin mixed with heavy oil. The viscosity of the mixture is about the same as that for length number 9. Length number 11 is impregnated with an experimental hydrogenated oil having a viscosity of 1,000 Saybolt at 100 degrees centigrade.

These two lengths are now being made ready for load-cycle endurance. It will be necessary to report results at a later date. We are planning to include other test lengths using high viscosity compounds and fully determine the best viscosity for gas-pressure cable of this type.

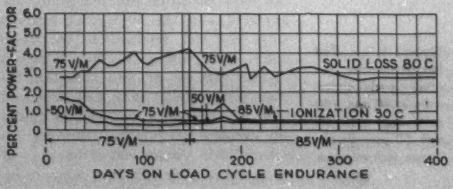

Figure 7. Test length number 6—load - cycle endurance at 80 degrees centigrade, 75 and 85 volts per mil—ten pounds per square inch nitrogen pressure

Summary of Test Conclusions

The series of tests already described lead to the following observations and conclusions.

Paper Tape

It is important that the paper tape be applied smoothly and uniformly with the smallest possible space between butt edges and freedom from wrinkling. Impregnating compound is held in the insulation by capillary attraction. This means that the largest spaces (voids) are drained first, leaving only a film of compound on the walls. One main object is to keep such voids to minimum size since ionization voltage is a function of void size at all pressures.

The thinnest paper tape allowed by practical limitations (five to six mils) should be used. Tearing of tape and wrinkling are the chief limitations in this respect. The need of freedom from impurities goes without saying.

Paper density over the usual commercial range from 0.8 to 1.2 seems to affect characteristics only slightly. If anything, the lower density paper appears to give a little better results but this is not fully demonstrated.

Impregnating Compound

The primary requirements, such as high resistivity, oxidation stability, etc., are common to all types of impregnated paper cable. The gas-pressure cable puts particular emphasis on stability and minimum gas evolution in the presence of ionization discharge.

Film tension and viscosity are other important requirements. The compound should have tenacity and not bleed readily from the paper insulation. Also, it should leave a thick film on the walls of the larger voids, thereby reducing their size and offering a source of *X* wax for closing up these larger voids and extinguishing incipient ionization locally

Table I. Insulation Thickness and Average Voltage Stress for Solid, Oil-Filled, and Low-Gas-Pressure Cable

Rating (Kilovolts)	Insulation Thickness (Mils)			Average Voltage Stress (Volts per Mil)		
	Solid	Gas	Oil-Filled	Solid	Gas	Oil-Filled
15	203	157	110	42.7	55.2	78.8
23	266	206	145	50.0	64.7	92.0
27	297	229	160	52.6	68.2	97.7
34.5	375	283	190	53.2	70.5	105.0
40	422	316	210	54.7	73.1	110.0

before it begins to spread and become cumulative.

The compound should not be of such high viscosity as to offer serious difficulties in obtaining uniform initial impregnation, or in draining the cable and gas channels sufficiently to prevent slug stoppages in service. Also, the compound should allow ready transmission of gas pressure through the insulation wall. Optimum compound requirements for gas-pressure cable are not yet fully determined.

Gas Pressure Medium

Of the readily available commercial gases it has been found that nitrogen is the most desirable. It has good dielectric strength, does not affect the solid insulation chemically, and its absorption by the impregnating compound is small. The present sources of supply specify a maximum oxygen content of 0.3 per cent. We are going to try to reduce this oxygen content. It has undoubtedly increased solid dielectric loss to a more or less extent in the tests that have been reported, by oxidation action during load-cycle heating. Other special gases of higher dielectric strength, similar to Freon are being given further study.

Ionization Stability

The development of low-gas-pressure cable was prompted by the observed behavior of ordinary solid-type cable when exposed to ionization discharge. There is a tendency toward cumulative ionization deterioration in solid-type cable. Observation shows this cumulative action takes place during periods of low temperature and negative pressure in void spaces. Maintenance of positive pressure, even if relatively low, will counteract this cumulative tendency markedly. A study of the low-gas-pressure cable bears this out. Initial ionization behaves in just the opposite way to that in solid-type cable. Instead of being cumulative in its action it is self-extinguishing and self-healing without permanent increase in solid loss.

This self-extinguishing effect is produced by formation of *X* wax which partially fills up the larger voids. Apparently, positive-pressure ionization, at voltage stresses below what might be termed a critical voltage, is not accompanied by the same harmful by-products that result from negative-pressure discharge, including gas evolution (mostly hydrogen) and conducting impurities (water and acids).

No doubt, the difference between ionization under negative and positive pressures is, in part, one of degree. With gas-pressure cable the size of voids and the pressure in these voids are under control. The critical voltage stress can accordingly be more safely approached. With solid type cable, however, neither the size nor pressure of voids is known or under control in all cases and there is always the possiblility of overstressing beyond the critical limit, which is not only lower than that of gas-pressure cable but variable and indeterminate.

Thermal Resistance

Measurements made after a year or more of 80-degree-centigrade load-cycle endurance give an increase in thermal resistance of the impregnated paper of from 10 to 15 per cent. This will have no practical effect on current-carrying capacity and it is proposed to give gas-pressure cable the same load rating as solid-type cable.

The possibility of using dry paper instead of impregnated paper was studied at the beginning and discarded for a number of reasons, one of these being the material increase in thermal resistance. The ready absorption of moisture upon exposure, the special precautions against this exposure, and the larger size of voids, offered other obstacles to the use of dry paper.

Critical Voltage Stress

It is proposed to operate low-gas-pressure cable at a minimum no-load pressure of ten pounds. The tests were accordingly made mostly at this pressure. Judging from these tests the critical average voltage stress is close to 100 volts per mil. We accordingly believe that a working voltage stress of no more than 75 volts per mil will give sufficient factor of safety, in view of the close control that can be obtained with cable of this type.

Economic Working Voltage Stress

Economically, the low-gas-pressure cable is very similar to solid-type cable. The accessories are equally simple and of practically the same size and cost. The gas channels, the drainage operations in the factory, and the various gas operations in both factory and field add a few per cent to cable cost. On the other hand, the reduced thickness of insulation and smaller diameter offer practically the same saving. Additional experience will be necessary in determining exact cost figures but, approximately, the curve for solid cable in figure 1 holds also for low-gas-pressure cable. On this basis, it can be seen that gas-pressure cable fits

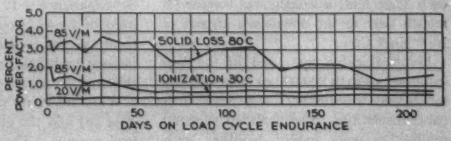

Figure 9. Test length number 8—load-cycle endurance at 80 degrees centigrade, 85 volts per mil—ten pounds per square inch nitrogen pressure

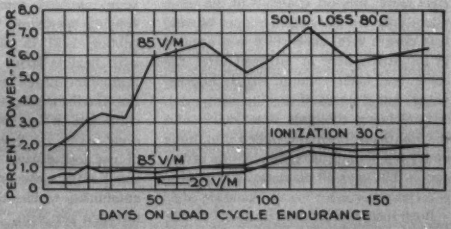

Figure 10. Test length number 9—load-cycle endurance at 80 degrees centigrade, 85 volts per mil—ten pounds per square inch nitrogen pressure

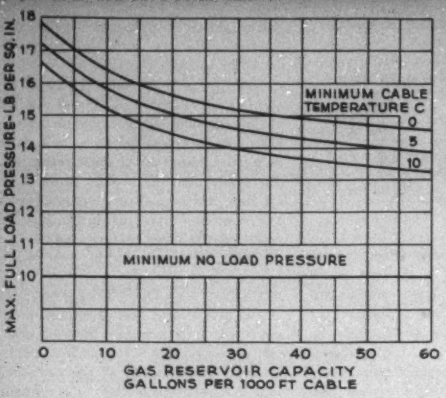

Figure 11. Fifteen-kv three-conductor gas - pressure cable system showing working pressure range as a function of auxiliary gas reservoir capacity, maximum copper temperature 81.5 degrees centigrade

into the economic picture best at 40 kv and below.

In determining insulation thickness for low-gas-pressure cable it is felt that a logical choice, as a starting point at least, is half way between the thicknesses for solid and oil-filled cable. Table I gives comparative thicknesses and average voltage stresses from 15 kv to 40 kv.

Field Installations

During the past summer (1938) the Consolidated Edison Company of New York and the Yonkers Electric Light and Power Company have ordered two trial installations of 15-kv low-gas-pressure cable. The first, consisting of a single three-conductor cable circuit 10,000 feet in length, was installed in Yonkers during August 1938, and is now in service. The second, consisting of two parallel circuits of three-conductor cable, each 5,000 feet in length, was installed a month later in the downtown district of New York City.

Identical cable was used in the two installations with 800,000-circular-mil sector-shaped conductors and 0.150-inch paper insulation. The insulated, shielded conductors were cabled together with steel spiral support channels in the three filler spaces. A single copper-bearing lead sheath 0.141 inch thick was applied in an atmosphere of nitrogen after the cable had been vacuum dried, impregnated, and drained of surplus compound. After leading the ends were sealed and the lengths shipped and pulled into ducts under ten pounds nitrogen pressure (average). The over-all diameter of this cable is 2.7 inches.

Both installations are paralleled in the same duct banks by solid-type cable of the same conductor size and voltage rating, also, the same current capacity rating and maximum copper temperature of 81.5 degrees centigrade. The Yonkers circuit has porcelain potheads at each end. The downtown circuits are spliced to solid-type cable at each end with stop joints at these points for segregation. No stop joints are used in either installation for sectionalizing, the gas feed channels having a free run from end to end.

These gas feed channels in each reel length were "blown out" with nitrogen gas before shipment and just before splicing in the field, to make sure no compound slugs were left. A few lengths showed a small amount of surplus compound in the feed channels. The majority of lengths were entirely free of slugs. The temperature and time of drainage before leading will be increased in the future until the correct values are learned by experience. It is expected that the need of blowing out slugs of compound from the gas feed channels, both in the factory and field, can be eliminated in this way.

When ready for splicing the cable ends were cut and the gas pressure reduced to two pounds. The exposed cable ends were plugged temporarily during the splicing operations with strips of sponge rubber, held in place and compressed with flexible band steel clamps. These temporary plugs were removed just before finally wiping the joint casing to the cable sheath and this last operation was done under gas flow. The total amount of gas lost during these operations was small after some experience was gained, amounting to less than 100 cubic feet of nitrogen per joint.

Because of the limited capacity of the filler-space feed channels and the desire to keep the gas pressure within a narrow working range from no load in the winter to full load in the summer, the Yonkers installation has galvanized steel tanks connected in the manholes to the cable joints at intervals of approximately 1,000 feet. These tanks are each of 53 gallons capacity and are, of course, filled with nitrogen gas to the same pressure as that in the cable. These tanks are simpler and more economical than the oil reservoirs frequently used with solid-type cable.

Figure 11 shows the pressure range of this 15-kv cable as a function of gas reservoir capacity. The curves are based on a minimum no-load winter pressure of ten pounds per square inch and show the maximum full-load summer pressure for different values of reservoir capacity. Three different winter ambient temperatures, zero, five, and ten degrees centigrade are assumed to illustrate their effects on cable pressure. With five-degree-centigrade winter temperature figure 11 shows the total working pressure range of the Yonkers installation to be from 10 pounds to 14 pounds.

For purposes of experiment no reservoirs were used in the downtown installation. Figure 11 gives a pressure range for this condition of seven pounds. To avoid stretching the lead sheath the maximum full load pressure is set at 15 pounds. This gives a total working pressure range from 8 to 15 pounds.

Accessories

The accessories used were much the same as those for solid cable of the same voltage rating.

Normal Joints

Similar to solid-cable joints with varnished-cloth tape reinforcement wrappings and metal shielding tape the full length of joint. The joints were filled with gas instead of compound and lead sleeve casings are seven inches diameter, offset toward the bottom to act as sumps for any surplus compound that might be drained from the gas channels. The casings are reinforced to withstand 15 pounds steady pressure.

In the future, on long lines where segregation for repair work is desired either stop joints will be used at intervals or semistops will be incorporated in some of the normal joints.

Stop Joints

Of the Herkolite core type used also with solid and oil-filled cable. The de-

sign has been described in a previous paper,[4] the only difference being that gas filling was substituted for oil filling and the cork-gasket semistops at each end omitted.

Potheads

Standard three-conductor porcelain potheads were used. A special cork-gasket semistop was incorporated in the wiping bell and the pothead above this semistop filled with petrolatum. The gas pressure below the semistop maintains the whole pothead under positive pressure.

Gas-filled potheads have worked successfully on laboratory and factory tests and will probably be used in the future.

Gas-Pressure Relays

Each installation has gas-pressure relays at the terminal ends, set to alarm at pressures a little above and below the normal working range. These pressure relays are of the bellows type similar in principle to those used with oil-filled cable but smaller and of lesser cost.

Profile

The profile of these first two installations is reasonably flat but, obviously, profile is of no consequence with gas-pressure cable. With solid and oil-filled cable profile must be taken fully into account on steep grades and at vertical risers. With gas-filled cable any height of vertical riser within the limits of mechanical strength can be safely used.

The gas-filled cable would appear to solve a real problem for use as risers in tall buildings and in localities where steep hills are encountered.

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4. Theory of Oil-Filled Cable, G. B. Shanklin and F. H. Buller. *General Electric Review*, July 1931.

Discussion

L. I. Komives (The Detroit Edison Company, Detroit, Mich.): We are glad to see a type of cable which in our estimation is designed primarily to relieve the lead sheath. It may seem that this aim is accomplished at the expense of the quality of the insulation; however, this may turn out to be merely an assumption. In any case, the ratio of the factor of safety of the insulation and of the lead sheath will be brought closer together by the means outlined by the author.

It seems that the remark in the paper that "profile is of no consequence with gas-pressure cable" would have to be proved in field installation. If this statement will be proved by successful field installations, we are looking forward to the use of this new type of cable for vertical risers.

In calculating costs, it should be borne in mind that most manholes are made for joints of more or less standard sizes. The author mentions joints seven inches in diameter with an offset toward the bottom which will certainly increase the size. Such large joints may necessitate the enlarging of present manholes.

When all accessories are taken into consideration, the low-gas-pressure cable differs from the oil-filled cable only in the use of accessories for gas supply instead of oil supply. From previous experience, we know that the oil-filled cable is a rather expensive installation. For this reason, until cost data are available, we seriously doubt the economy of this type of cable as against the standard solid-type cable for voltages below the 38 kv as mentioned by the author.

Robert J. Wiseman (The Okonite-Callender Cable Company, Passaic, N. J.): I have read with great interest Mr. Shanklin's paper as he describes the trials, tribulations, and hopes of an investigator of a cable design which is not too well known in commercial practice.

Cables in which gas is used as a means for maintaining the quality of the insulation are not new and we find many patents describing specific designs. Almost all of them pertain to the use of gas under high pressure. For some unknown reason, mostly everyone wants to operate the cable around 200 pounds per square inch internal pressure, yet it is possible to get commercially very good stability as low as 75 pounds per square inch pressure and we do not have the problems of leakage that exist at high pressures.

I am not so sure that solid-type cables have about reached their ultimate development. As I view it, we can improve solid-type cables if we loosen up slightly on the tightness of our sheaths and design our joints to permit free flow of oil between the joint and cable. This means the elimination of the varnished-cambric wrapped joint and the use of tubes as was done years ago with a fluid oil in the joint instead of hard or solid compounds. Tests we have conducted in our laboratories have shown an increase in life of a cable. A simple solution to the problem, yet it is to be regretted that we are wedded too much through custom to the use of tightly wrapped and solidly filled compound joints. Granted that the joint may not have as high a breakdown voltage as a tightly wrapped joint, it is more than ample for operation and at the same time, we reduce the pressures which a cable will be subject to and also prevent the cable dropping to a high vacuum when cooling.

It is true that the low-pressure oil-filled cable has contributed to the success of high-voltage cables and it is a question of economics whether it should be used or solid-type cable. The high-oil-pressure cables are equally able to meet the needs of high-voltage operation and are also dependent on the economics of the installation. The jointing is not as difficult as for the low-pressure oil-filled cable as the oil is of a higher viscosity and will not bleed from the cable during the making of a joint. It is true that the reinforcing is more expensive, but with the higher voltage breakdown which is obtained on the high pressure, it is a question of what factor of safety is desired and the price one wishes to pay for it.

The high-gas-pressure cable has been proved successful in Europe. We have the Beaver design which is the same design as Mr. Shanklin gets by drainage, as Beaver uses preimpregnated paper and his method of manufacture eliminates the filling in of the paper gaps and between layers with oil. Beaver uses 200 pounds per square inch N_2 gas pressure. The Hochstadter gas-pressure cable has a lead sheath between the insulation and the gas and the latter does not function as a part of the insulation. The Callender's Cable and Construction Company have two designs of high-gas-pressure cable, one uses impregnated paper and over the paper is wrapped varnished silk tapes before the shielding tape is applied. A loose lead sheath permits the filling of the space between the cable and the sheath with N_2 gas at 200 pounds per square inch pressure. The varnished silk tapes prevent the oil from draining from the cable and also the absorption of gas by the oil, thereby maintaining stability of the insulation. This type of cable has been under successful test for two years at Arnhem, Holland, and is the only design of high-gas-pressure cable with impregnated paper that has been successful. It has only been equalled by a low-pressure oil-filled cable which uses a heavier wall of insulation and a lower maximum stress. In addition, Callender's have been testing a similar type of impregnated gas-pressure cable in their own research laboratory for several years, first at 200 kv with the same current required at Arnhem, later they raised the voltage to 300 kv and to date the same cable has withstood 65 load cycles at 85 degrees centigrade on the copper. We also have made and tested an impregnated gas-pressure cable in our laboratories and have proved in its stability with tests on a 500,000-circular-mil round conductor, 0.450-inch wall, starting at 95 kv (312 volts per mil maximum electric stress) for 1,482 hours and 133 kv (438 volts per mil maximum electric stress) for 549 hours. The cable did not show any ionization between 35 volts per mil and 170 volts per mil both hot and cold for the last 20 days of test. The power factor was about 0.48 per cent at 70 degrees centigrade and 0.53 per cent at room temperature for the last 20 days of test.

I believe the reason for the failure of the cable which Mr. Shanklin tested at 200 pounds pressure was due to the absorption of gas into the oil with the resulting lowering of the dielectric strength and the increase in power factor. During our studies eight years ago on our Oilostatic cable system we used gas as the pressure medium and a gas cylinder was connected directly

to the potheads at 200 pounds pressure. Every few months we noted an increase in the power factor of the pothead which required draining of oil and refilling. The drained oil was milky in appearance and had about 20 per cent gas content. We introduced an intermediate oil reservoir with a diaphragm between the gas cylinder and the pothead which eliminated the trouble. The important thing is to keep the gas from contact with the oil that is under stress. The success of the Callender's impregnated gas-pressure cable comes from the varnished silk between the insulation and the gas.

Mr. Shanklin is using for the low-gas-pressure cable, comparatively low electric stresses but it is the maximum stress at the conductor that is important. According to figure 2 at 15 pounds per square inch gas pressure, ionization starts at 70 volts per mil and to be safe, one should take not over 80 per cent of this or 55 volts per mil. This does not agree with the statement under "Critical Voltage Stress" in which Mr. Shanklin proposes a working stress of 75 volts per mil. In other words, it is necessary to increase his wall thickness. Although the mixing of gas and oil is not as serious as if high gas pressure were used, still with time as expressed in years it seems as if there will be sufficient gas absorption by the oil seriously to reduce the breakdown voltage of the cable. Perhaps today we are not as concerned about getting high-voltage breakdown of our cables as we did formerly, in which case the cable manufacturer can take advantage of it as suggested above for solid-type cables. The need of as low gas absorption as possible is shown by the different results which Mr. Shanklin obtained with CO_2 gas and N_2 gas. The former is easily absorbed into oil, the latter with great difficulty but also hard to remove once it is absorbed.

Mr. Shanklin very nicely describes the problems in manufacture of a low-gas-pressure cable where the oil is permitted to drain. The size of voids is the controlling factor in stability and, therefore, careful taping is essential.

I am surprised to note that the thermal resistance is only 10 to 15 per cent higher than solid cables. I would expect it to be much higher. Tests on insulation subject to high gas pressure show a value of about 660 thermal ohms per centimeter cubed. Perhaps Mr. Shanklin has in mind as a reference value the 700 thermal ohms per centimeter cubed which we now use for paper cables and, therefore, actually about 800 thermal ohms per centimeter cubed. New solid cable shows as low as 450 thermal ohms per centimeter cubed but due to oil migration and drainage, with time, the 700 thermal ohms value is used in calculations. His curves of load-cycle endurance indicate a higher power factor than we are getting for solid cables and, therefore, it is questionable that the same current-carrying capacity can be used as for solid cables when we also consider the higher thermal resistance.

I am glad to note that this cable design is to be limited for the present to low voltages as it is essential that operating experience be gained to find all the sources of weakness that may be present, such as porosity of joint wipes and the ultimate absorption of gas to the saturation point. I wish to congratulate Mr. Shanklin on a most interesting and well-prepared paper on another cable design which may have its usefulness provided we are willing to accept a lowering of some of our past requirements, namely, high-voltage breakdown, low power factors, and not too high thermal resistance.

E. W. Davis (Simplex Wire and Cable Company, Cambridge, Mass.): Mr. Shanklin's paper brings out the details of a very interesting new development in cable using a semi-impregnated paper cable supplied with moderate gas pressure to increase reliability by compensation for expansion and changes in the insulation due to load cycles.

The new design is one of the many new trends in cable progress which employ, more and more, various pressure devices to improve cable operation, increase allowable stresses, and remove some objectionable characteristics developing as a result of service practice.

It promises well but being intermediate between oil-filled and gas-filled cables must possess some good features of each and also some objectionable ones. Oil-filled cables under pressure have high impulse strength to transient voltages and since the insulation is voidless no damage should be present from overvoltage up to failure point. Gas-filled cables on the other hand have somewhat lower impulse strength but overvoltages usually produce self-healing faults.

The low-gas-pressure cable is midway between these and provides a composite dielectric of three components, oil, paper, and gas. Transient voltages sufficient to ionize gas-filled voids would not necessarily be self-healing and might produce permanent damage which would later develop into trouble. We are wondering if impulse tests have been made on these cables and faults obtained examined or if high-voltage life tests have shown the effect. The paper, under "Impregnating Compound," indicates that the weakness has probably been considered by the author. We note that long-time ionization is said to make self-healing voids by the formation of X. This takes time and would not take place with high transient voltages.

W. F. Davidson (Consolidated Edison Company of New York, Inc., New York, N. Y.): Mr. Shanklin has presented an interesting discussion of a new type of cable which we are glad to welcome in the American market. It is encouraging to see progress being made in the direction of new types of cable because it seems that this offers one of the most encouraging means for reducing the over-all cost of cable systems.

My first specific comment is to quarrel with the use of the term "negative pressure." When we are dealing with gases or liquids, such a term is quite meaningless in spite of its use in technology and it has the serious objection of possibly leading us astray when we come to analyze the underlying phenomena.

In his discussion under the heading "Ionization Stability" the author suggests that there is a "difference between ionization for negative and positive pressures." For any fixed electrical stress, there is a difference in the intensity of ionization but I am unfamiliar with any theory which will account for a difference in the action. Is ionization of any degree objectionable and if so, what determines the border line? The author suggests that there is something more than a difference in degree and it would be of great interest to all of us to know something more as to the details.

L. J. Berberich (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): The results given by the author on the low-gas-pressure cable indicate a better performance under load-cycle test than one would expect. Gas pockets exist and ionization admittedly occurs just as in the solid cable with the one important difference; namely, a positive pressure is maintained in the gas pockets at all times. This naturally raises the critical voltage at which ionization begins. The success of the cable, however, appears to be in the discovery made by the author and his associates that ionization as measured by power factor change with voltage becomes negligible after the cable has been subjected to load-cycle test for a time.

This diminution of ionization with time on load-cycle test is ascribed to a self-healing process in which the area surrounding the gas pockets is sealed with the solid polymerization product formed as a result of the discharge. If this is true, an oil that produces large quantities of wax on subjection to corona discharge may be desirable. In this connection, I would like to ask if the addition of some aromatic compound, such as diphenyl, to the impregnating oil has been tried. In my work along these lines (*Industrial and Engineering Chemistry*, volume 30, 1938, page 280), it was shown that compounds of the aromatic type decrease the gas evolution from oils markedly and may increase the wax formation; the latter, however, could be observed only in a qualitative way. It appears possible that such additions to the impregnating oil may have application in this type of cable.

The authors report that when the high-dielectric-strength gas Freon was introduced into the cable, a very short life was obtained. It is questionable whether any of the high dielectric gases will be satisfactory as pressure mediums in this cable. Most of these gases are hydrocarbons which are either chlorinated or fluorinated or both. Compounds of this type are known to split off halogens under conditions of corona discharge. Since oil is also present which is an abundant source of reactive hydrogen under these conditions, the formation of strong acids is very likely. Some of these gases have hydrogen in the molecule which may provide another source for hydrogen.

Victor Siegfried (Worcester Polytechnic Institute, Worcester, Mass.): Mr. Shanklin has described an interesting solution for some of the problems involved in paper insulation of high-voltage cables, where the ionization of gaseous voids seems to be the limiting factor in the voltage rating of the cable. The philosophy of his method seems to reverse that of the cable using oil under pressure, and appears to be that if the inevitable voids in oil-filled cable establish

the working limit of voltage, let us then design the cable to have only voids, but control the effect of the voids by definite regulation of the pressure of the gas in them. This method of attack has led therefore to the use of gas at relatively low pressure and simple mechanical features, beyond which pressure, the economics and other factors involved indicate diminishing returns for any further increase in pressure.

There is one point in regard to which the language should be kept clear, however. This cable uses paper insulation, with gas under pressure as the saturating medium. I would prefer to classify this cable as a *gas-filled cable*, leaving the *pressure cable* designation open to future developments of cables at much higher gas pressures. The conclusions which the author presents indicate an optimum pressure of about 40 pounds per square inch pressure for this type of cable, whereas for real high-voltage cables using gas as the major dielectric, higher pressures appear to be economically desirable to realize the full benefit of the gaseous insulation properties. Mr. Shanklin's work is valuable in its field, but there is much room for development and research along the lines of a real gas-pressure cable using the higher optimum of pressure.

Wm. A. Del Mar (Phelps Dodge Copper Products Corporation, Yonkers, N. Y.): This paper is probably destined to be one of the classics of cable engineering as it is one of a very few that have appeared announcing the development of an entirely new type of cable.

Like most new inventions many close approaches have been made to it but, for one reason or another, they did not, so to speak, "go over the top." There is nothing new in a drained cable or in gas pressure or even in the combination of a drained cable with internal gas pressure. The invention, as I see, lay in the realization that a limited gas pressure would give to a drained cable a sufficiently high ionization point to permit a cable of economical dimensions to be designed for the voltages at which three-conductor solid-type cables are used. Hitherto, workers with gas pressure cable had concentrated their efforts on the higher voltage field already occupied by the oil-filled cable.

Our laboratory has worked on a drained paper cable, with interstitial gas at atmospheric pressure. With this cable, the rise of the ionization point with continued application of voltage was as definite as in Mr. Shanklin's cable. Ionization started at a maximum stress of 50 volts per mil, calculated by the ordinary logarithmic formula. The stress was then raised to 60 volts per mil at which the dielectric loss was eight times as great as that at 50 volts per mil, and continued for three months at room temperature. During this period the ionization stopped. The voltage was then raised until ionization started, and it was found that the critical stress had risen to 65 volts per mil. I do not believe that ionization ceased at 60 volts per mil, as the result of filling the interstices with cable wax, as suggested by Mr. Shanklin, as very little wax was found.

Furthermore, a nitrogen-gas-filled cable at 30 pounds per square inch absolute pressure tested for 40 heat cycles at *zero voltage* showed a steadily decreasing ionization. Whereas for the first 10 cycles the power factor at 100 volts per mil ran over three times that at 60 volts per mil (average stresses), after 40 heat cycles, there was little difference between the power factors at the two stresses, that at the lower stress having remained constant. All I can say about the cause of this suppression of ionization is "I don't know." It would make a nice subject for a university thesis.

The ionization point of drained cable was also raised by the use of carbon-compound gases instead of air or nitrogen but these introduced difficulties peculiar to the gases employed.

The maintenance of pressure by the low-pressure-gas cable depends on the integrity of joint wipes and particular care will be required in testing for leaks. It is possible that a test similar to the soap bubble test will be useful, using instead of soapy water, such a material as Nekal, a product of I. G. Farbenfabrik, which is claimed to be much more efficacious than soap solution.

The impulse transient dielectric strength of drained cable is only about 15 per cent less than that of well-impregnated cable, so that on that basis, insulation walls would not have to be more than 18 per cent greater than those of oil-filled cables, which are based on impulse strength. It would therefore seem that Mr. Shanklin's table of thicknesses is conservative.

There are, of course, features of uncertainty in this cable which only time will clear. One of these is whether the eventual drainage of oil from the paper will not unduly lower the dielectric strength of the insulation. Another is the effect on the lead of long continuous application of the moderate pressure used. Laboratory tests indicate that while the stretch of lead is slow at such pressures, it is nevertheless definite and certain and that it occurs at an accelerating pace, as the lead becomes thinner. In view of such uncertainties inherent in a pioneer installation, the Consolidated Edison Company deserves the thanks of the industry for taking the initiative.

Joseph Sticher (The Detroit Edison Company, Detroit, Mich.): The paper by Mr. Shanklin brings out an apparently beneficial action of wax in cables. The beneficial action of wax referred to here consists of the closing up of larger voids and the extinguishing of ionization in these voids before it begins to spread and become cumulative. Until recently, cable wax was looked upon as visible proof that deterioration was occurring in the cable insulation and that this would eventually lead to breakdown of the cable. Wax was therefore abhorred and efforts were made to develop cable impregnants which would produce a minimum of wax when subjected to corona discharge.

During the past decade and more The Detroit Edison Company has studied the effects of corona discharge on oils and oil-impregnated papers with the view of determining changes in the electrical, chemical, and physical characteristics. From the results of this study, some of us gained a new viewpoint regarding cable wax, as follows:

It appeared that possibly wax should not be abhorred but really welcomed since it might be looked upon as a sort of natural self-defense of the cable against the ravages of ionization occurring within it. This conjecture was expressed in a paper presented before the National Research Council in November 1938. ("The Effect of Corona Discharge on Cable Insulation," Joseph Sticher, D. B. F. Thomas, C. D. Robb, and F. M. Hull; presented at the Conference on Electrical Insulation of the Division of Engineering and Industrial Research of the National Research Council, November 3–4, 1938, at Pittsburgh, Pa.)

The results which Mr. Shanklin relates in connection with tests on various test lengths of cable are very interesting in that they show that ionization under a given set of conditions gradually disappeared, to reappear only after an increase of voltage. These results are in support of the suggested hypothesis of self-defense of the cable in the following manner:

The gradual disappearance of ionization seemed to be due to formation of wax in voids. This wax tended to decrease the size of the voids with subsequent load cycles until ionization could not be maintained any longer at the prevailing voltage gradient.

When this apparently beneficial action of cable wax is considered still further, it appears that it might have potential possibilities to aid in the constant efforts to improve solid-type oil-impegnated paper cables somewhat as follows:

If a cable impregnating compound were found or developed which would form wax very rapidly under ionization, voids in a cable impregnated with this compound would rapidly be filled with wax to the extent that ionization would be extinguished. A certain amount of increase in total void volume would result from this waxing because of the increase in the density of the compound during the polymerization or condensation. The voids making up the total void volume would, however, then consist of two classes: first, voids too small to be ionized even in the region of highest voltage gradient; second, all voids including maximum size located in regions of voltage gradient too low for ionization to occur. In this connection it should be pointed out that compounds which form wax readily under corona discharge, such as unsaturated and aromatic oils and certain of the naturally occurring sulfur compounds, are at the same time compounds which produce only a little gas under this treatment. This coincidence is of decided advantage in the present application. In the unsaturated class, olefins such as hexadecene and higher homologs; or turpenes such as pinene or higher homologs, or polymerized products of turpentine; or in the aromatic class, polyindene or homologs of xylene; or in the sulfur class, the sulfides, might be desirable. It must also be realized that the wax, to be of use in this cable, should not be soluble in the impregnant and should not carbonize in the time it takes for ionization to be extinguished.

Whether a cable could save itself in this manner would depend essentially on what might be called the "waxing ability" of the impregnating compound. If this waxing ability is low, the insulation might fail before sufficient wax could be formed adequately to reduce the size of the affected voids.

Efforts "to fill the economic gap caused by the relatively high cost of oil-filled cable below 38 kv" would be best served, it seems, by improvements of the solid-type cable, which would allow this type of cable to remain self-contained. The *H*-type cable is an example of such an effort and that improvement has gone a long way toward solution of the problem. In other improvements of the solid-type cable a considerable amount of auxiliary equipment is usually entailed. The low-gas-pressure cable appears to come close to the "self-contained" solid-type cable. If, however, a freely waxing cable impregnant, used in place of the present impregnants, is developed to extinguish ionization as indicated, then a truly "self-contained" solid-type cable of

satisfactory performance may possibly result.

G. B. Shanklin: Mr. Del Mar's kind and encouraging remarks about this development are very much appreciated. His comments regarding the self-healing effect of ionization on a test length of drained solid-type cable are quite interesting. Mr. Del Mar states that he obtained this self-healing effect without pronounced *X* wax formation which invariably accompanies the same effect in the low-gas-pressure cable. I think the difference is explained by the physical construction of the two cables. Mr. Del Mar's cable did not have longitudinal feed channels for maintaining uniform gas pressure. The pressure in voids accordingly must have varied over a wide range with load cycles, and ionization gradually improved as the cable became gas-saturated with a gradual increase in pressure.

I readily admit that formation of *X* wax may not be the entire answer to this improvement in ionization in the gas-pressure cable. Perhaps further investigation will bring out additional factors. Our work shows however that formation of wax is without doubt one of the major factors in this self-healing effect. To give the best results this wax formation should be accompanied by a minimum amount of by-products, such as gas evolution, water, and other conducting impurities.

In regard to the possibility of porous wipes and other sources of leakage, it might be pointed out that the gas-pressure cable system is self-maintaining and so far there has been no difficulty in locating and repairing leaks that in an ordinary solid-type cable system would not be discovered until service failure occurred. The two field installations described in the paper are now completely gas tight, and no real difficulty was experienced in obtaining these results.

Mr. Del Mar has analyzed the transient impulse strength characteristics of the gas-pressure cable very accurately. This cable has an impulse strength midway between that of oil-filled cable and solid-type cable. We are in no way worried about the sufficiency of impulse strength in service.

Referring to the question raised by Mr. Del Mar regarding the possibility of continuous drainage of compound in service, we have subjected lengths of this cable to severe load cycles over a period of two years or more and have found in every case that drainage of compound from the paper insulation stabilized in a relatively short time and after a balance was reached between gravity and capillary attraction. The total drainage before this balance is reached is a function of compound viscosity and film tension (tackiness).

Mr. Del Mar also raises the question of gradual and continuous sheath creepage in service. Fortunately we have had a good deal of experience with oil-filled cable and sheath creepage has also been exhaustively studied in the laboratory. This work has shown that when the stress on the lead sheath does not exceed 125 pounds per square inch of sheath no appreciable creepage takes place.

Messrs. Berberich and Sticher both have a very accurate and parallel conception of the low-gas-pressure cable. The principle upon which this cable is based is in many ways opposite that generally accepted for solid-type cable. In the past, as Mr. Sticher states, ionization and wax formation in a cable have been abhorred. I think the chief reason for this is that wax formation in solid-type cable is usually accompanied by wide pressure fluctuations and undesirable by-products, such as gas evolution, water, and other conducting impurities. The wax itself has not been the real culprit.

In the gas-pressure cable the goal aimed at is uniform pressure maintenance and maximum wax formation with minimum gas evolution and by-products. The test results given in the paper show that this goal has now been closely approached. We are actively continuing our study of the most favorable compound characteristics, and we hope in time to obtain further improvements in this direction. We intend to continue our present trials of all possible compound compositions. So far we have found that the compound requirements for this gas-pressure cable are not greatly different from those for ordinary solid-type cable as regards stability and long life.

Referring to Mr. Davidson's discussion, I plead guilty of loosely using the term "negative pressure." It is more an expression of convenience than scientific accuracy and is uscd for the purpose of avoiding confusion in referring alternatively to absolute zero pressure and atmospheric zero pressure.

The last question raised by Mr. Davidson can only be answered by a good deal of additional research. I can only say that our work seems to indicate that there is more than merely a difference of degree in the effects of ionization at different pressures. Ionization in a partial vacuum seems to lead to more harmful gas evolution and more conducting by-products than corresponding discharges at higher pressures. Whether this is a question of differences in mechanism, chemistry, or both, I do not know.

Replying to Mr. Komives, it is not our purpose intentionally to lower the insulation quality in gas-pressure cable for purposes of obtaining better sheath performance. Actually we hope to obtain both better insulation quality and better sheath performance as compared with solid-type cable. We believe that the tests described in the paper bear this out. The gas-pressure cable remained stable under severe load-cycle heating at an average stress of 85 to 100 volts per mil. If stability under these conditions is accepted as a criterion of quality, we do not believe that ordinary solid-type cable could show any improvement.

Mr. Komives raises a question regarding the relative size of the joint casings for gas-pressure cable. It is true that the joint casing diameter is larger for purposes of acting as a sump. The length of the joint however is exactly the same as that for solid-type cable of the same voltage rating. It is length and not diameter of joints that is affected by manhole dimensions.

E. W. Davis asks about the impulse strength of this gas-pressure cable. I believe this question has already been answered in Mr. Del Mar's discussion. We believe the impulse strength of this cable to be somewhere between that of corresponding oil-filled and solid-type cable.

Doctor Wiseman seems to feel that solid-type cable can be improved by providing more ready means of longitudinal flow of compound. He suggests that a loose-fitting lead sheath and joints without reinforcement wrappings will help in this respect. This happens to be a possibility we have given a good deal of study to in the past. The whole trouble is that these changes will introduce all of the difficulties of oil-filled cable without the compensating benefits. As with oil-filled cable, it would be necessary to accept cumulative hydrostatic head pressure and control this with stop joints, reservoirs, etc. The benefit of this complication would not be obtained however, since it would be impossible also to control and maintain positive pressure over the whole cable length during load cycles. This can only be done with a relatively thin oil and sufficiently large longitudinal feed channels, in other words, an oil-filled cable. There is nothing in between as far as oil feed is concerned.

I cannot see any real benefit in the type of high-gas-pressure cable described by Doctor Wiseman, having wrapped varnished silk tapes over the cable insulation which act as a semi-impervious membrane. It seems to me that these silk tapings would merely retard but not prevent gradual gas saturation of the impregnated paper insulation. They would also interfere with initial drying and impregnation treatment in the factory and maintenance of uniform pressure throughout the cable cross section in service. It was for these reasons that we abandoned the idea of semi-impervious wrappings in the low-gas-pressure cable, where, at best, pressure is at a premium and there is none left to waste.

Doctor Wiseman seems to have missed the point that the low-gas-pressure cable is gas-saturated before it is shipped from the factory. This is accomplished as part of the regular factory treatment, and the reel lengths of cable are shipped under gas pressure. He need have no worry, then, about the effects of gradual gas absorption during service.

Reverse-Rotation Test for the Determination of Stray Load Loss in Induction Machines

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VARIOUS methods for the accurate determination of stray load loss in induction machines have been devised in recent years. Also older methods have been improved and developed as the nature of the loss has become better understood. The employment of different methods of testing on a given machine seldom shows complete agreement in results, due to minor discrepancies and inaccuracies inherent in the methods themselves. Another difficulty is that all of the plans proposed to date require a high degree of skill and experience on the part of the testing technician. Thus industry today finds itself in need of a test which will give highly accurate results and at the same time be simple and easy to perform. The purpose of this paper is to describe a new method of testing—termed the "reverse-rotation test"—which will more nearly meet these requirements. The theoretical basis and the assumptions involved are discussed. Tests to determine the accuracy of the method have been made on two squirrel-cage motors of somewhat different characteristics by various methods of testing. The results of these investigations are described and curves are given showing the degree of exactness obtained. While the method includes assumptions regarding compensating effects involving minor components of the loss, its over-all accuracy for the motors tested is shown by comparison with the values obtained by other methods having high precision.

Advantages

While the accuracy of the reverse-rotation method of determining stray load loss has not yet been thoroughly established for all types of induction machines, the results of the experimental work described herein prompts the following claims:

1. This method will give highly accurate results and at the same time the test is simple and convenient to perform.

2. The value of the losses can be determined quickly without the use of special apparatus—the only requirements being a source of power having adjustable polyphase voltage and a driving motor for which the losses can be determined.

3. Laborious computations are avoided and final determinations of the value of the stray load loss can be obtained in a few moments by simple calculations from the measured quantities.

Test Procedure and Computations

The reverse-rotation test is carried out by applying reduced balanced polyphase voltage to the stator terminals of the machine being investigated while driving the rotor at synchronous speed in the direction opposite to that of the revolving stator field. The stator current may be set at any desired value by adjustment of the applied voltage. Two power measurements are necessary: the power required to drive the rotor and the power input to the stator circuit. Let the former be designated by P_r and the latter by W_s. The power required for rotation of the motor rotor (P_r) may be obtained by driving it with a sensitive dynamometer or a motor with known losses. The friction and windage losses at synchronous speed of the motor under test are also required and may be designated by P_f. The difference between these two quantities gives the component of the net input to the rotor which is supplied through the driving mechanical power. If this net power resulting from rotation be represented by P, then:

$$P = P_r - P_f$$

When a d-c motor is used to drive the induction machine, correction for losses in the d-c motor becomes a simple matter if the same value of field current is used for both the load and the no-load determinations, obtaining constant speed by armature voltage control. The difference in the armature-circuit brush and copper losses of the d-c motor is the only correction that must be applied to the difference of the two d-c input values in order to determine the net power P, since all other losses in the driving machine remain constant.

The total stator power input W_s is carefully measured by wattmeters for the particular value of current used. An accurate measurement of the stator d-c resistance is made at the winding temperature used during this power observation. The total polyphase stator copper losses are then computed and may be designated by W_{cu}. When subtracted from the total stator input (W_s) there remains the net stator power which may be called W, and:

$$W = W_s - W_{cu}$$

The value of stray load loss for the particular stator current used is then obtained as the difference between net rotor input and net stator power, or

$$\text{stray load loss} = P - W$$

Experience indicates that it is easier to obtain accurate test points over the range between full-load current and about double this value. If points are determined over this range of current the value of the stray load loss for any desired current can be computed readily by application of the law that the loss varies as the square of the current. The curve for the working range of the motor is obtained simply in this manner.

Light-Load Correction

In order to satisfy the definition of stray load loss it should be zero at no load. This desired result is obtained by calculating the loss for no-load current and subtracting its values at this point, that is, simply making the loss zero at no load. At the one-half load point one-half the correction necessary for no load may be applied, and at full load no correction is necessary.

Discussion of Principles

The stray load loss in induction machines is defined as the residual power

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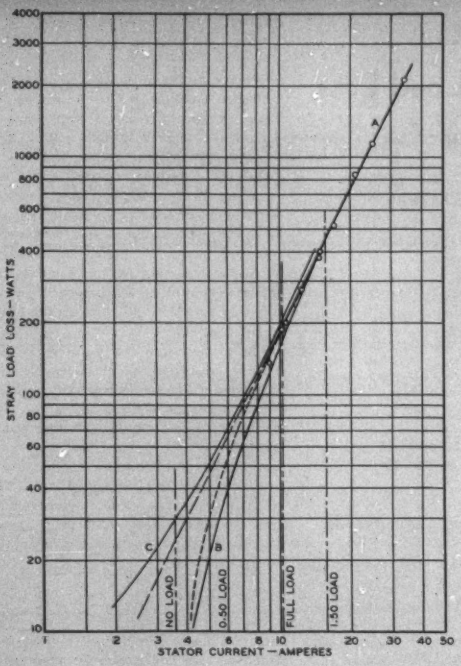

Figure 1. Stray load loss curves for motor 1

A—Loss by reverse rotation method. Dashed line is straight line extension; dotted line shows loss after light-load correction is applied

B—Loss by load-back through belt

C—Loss by load-back through belt, including added component for no-load current

loss after all other known losses are considered in accordance with specified methods of measurement.[1] The loss consists chiefly in the increase in iron and copper losses occurring as a result of the load current in the stator and rotor circuits while the rotor is revolving. The total stray load loss may have components at tooth frequency and at fundamental frequency, the former being of major importance. The reverse-rotation method of testing gives a measurement of all tooth-frequency components and includes the fundamental-frequency components only through compensating effects. The test procedure also assumes that the direction of rotation of the rotor with respect to the direction of the fundamental flux does not alter the magnitude of the tooth-frequency losses, since in both cases the tooth-frequency fluxes are superimposed upon fundamental-frequency fluxes.

When the rotor of the machine is turned at synchronous speed in the direction opposite to the field flux all power supplied is consumed in losses. The total power input consists of electric power through the stator and mechanical power supplied through rotation ($W_r + P_a$). After subtracting stator copper losses and friction and windage losses from the total power input (both electric and mechanical) the remaining losses may be classified in three frequency categories: (1) fundamental-frequency losses caused by the leakage flux of the stator, (2) double-frequency losses in the rotor resulting from reverse rotation, and (3) tooth-frequency components of the stray load loss occurring in both rotor and stator. The stator fundamental-frequency losses caused by the leakage flux, which are apparently very small, are not considered at this point and only included in the final result through compensating effects to be explained later. The double-frequency rotor losses result from currents in the rotor conductors and fluxes in the rotor iron at this frequency. With rotation at synchronous speed in opposite direction to the stator field the double-frequency rotor losses are supplied in equal amounts from the power of rotation P and from power transmitted by the stator circuit through the air gap W. The tooth-frequency losses result directly from rotation, and consequently

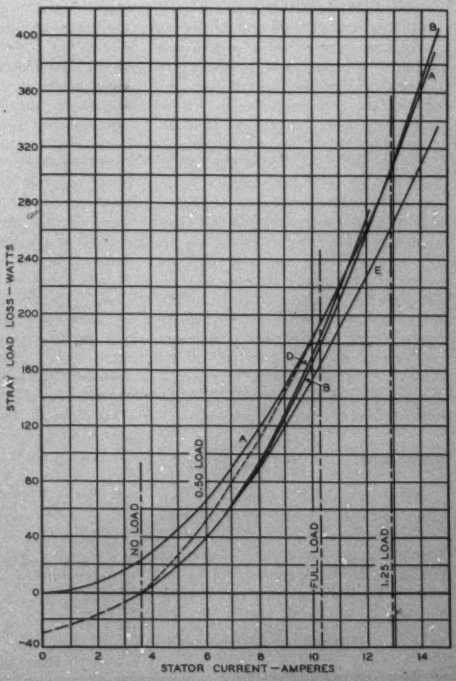

Figure 2. Comparison of stray load losses for motor 1 determined by different methods

A—Loss by reverse rotation method. Dotted line shows loss after light-load correction is applied

B—Loss by load-back through belt

D—Loss by load-back through d-c machines

E—Loss by d-c excitation of stator

1. For all numbered references, see list at end of paper.

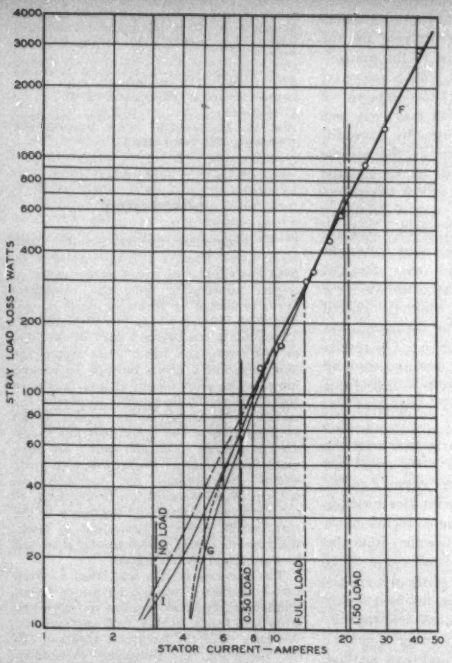

Figure 3. Stray load loss curves for motor 2

F—Loss by reverse-rotation method. Dashed line is straight line extension; dotted line shows loss after light-load correction is applied

G—Loss by load-back through belt

I—Loss by load-back through belt, including added component for no-load current

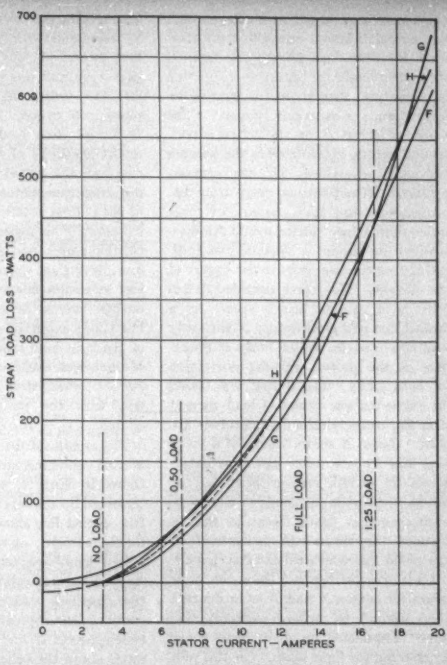

Figure 4. Comparison of stray load losses in motor 2 as determined by different methods

F—Loss by reverse rotation method. Dotted line shows loss after light-load correction is applied

G—Loss by load-back through belt

H—Loss by d-c excitation of stator

are supplied only by mechanical power. Thus the net power input through rotation P consists of one-half the double-frequency rotor losses and the total tooth-frequency losses. By subtracting from this quantity P the air-gap power supplied from the stator W, the tooth-frequency losses are separated out and given as the remainder.

The question may be raised regarding the amount of the error introduced by neglecting the component of the stray load loss which might be assumed to exist because of the fundamental-frequency leakage flux. As a matter of fact, the proposed treatment not only neglects this component of the loss but includes it in the stator value W which is subtracted from the net rotational power input component P, thus doubling this error. However, the fundamental-frequency component of the stray load loss is very small and any error resulting from this treatment is evidently compensated by other small errors involved in the method. These may be listed as follows:

(*a*). The iron of the motor is worked at low saturation during this test which tends to give a higher value of stray load loss than would exist under normal saturation conditions.

(*b*). Synchronous speed is slightly higher than normal speed of operation, giving a slightly larger value of stray load loss (which varies as the square of the speed).

(*c*). In the application of test results to motor performance the currents used during the test are considered as stator input currents under load conditions. During the test, due to the absence of the exciting component, the stator current has a corresponding rotor current, while under actual motor operation the rotor current is less than the stator current. This slight increase in rotor current under test conditions gives a larger value of stray load loss for a given stator current than actually exists under normal operating conditions.

The above items separately appear of minor importance but they all act in the same direction and tend to compensate for the omission of the fundamental-frequency component of the stray load loss, which is evidently a small quantity. Experimental results indicate that this compensation is approximately complete in the region extending from 150 per cent load to well below full-load. At light loads a small correction is necessary, and the purely arbitrary method previously proposed is probably sufficiently accurate for all practical purposes and it has the advantage of being simple and easy to apply.

Test Results

Motor 1

The first motor tested was of the squirrel-cage type and was rated at 10 horsepower, 550 volts, 10.3 amperes, 3 phase, 60 cycles, 1,750 rpm. This motor had

previously been tested with extreme care by several different methods to determine its stray load losses.[4] In figure 1 stray load losses are shown as a function of armature current when plotted on logarithmic cross-section paper. The points of curve *A* are the actual experimental points, determined in the manner previously described, by the reverse-rotation method over a range from approximately full load current to three times that value. These points fall on a straight line having a slope of two, indicating that the loss varies as the square of the current. This curve extended downward as a straight line is shown by a dashed line and gives values of the stray load loss over the normal range of operation of the motor omitting correction for light loads. The dotted line shows the curve for low values of load current after the correction for light loads is applied. Curve *B* shows values of a stray load loss for the same motor as determined by careful measurement by the belted load-back method.[3] Curve *C* is the same as curve *B* except that it includes the theoretical component of stray load loss which exists at no load.[3,4]

The curves of figure 2 show the same values for curves *A* and *B* as in figure 1 when plotted to uniform-scale co-ordinates. The dotted line curve shows curve *A* corrected for light loads. On this plot values of stray load loss, determined with a high degree of precision by the load-back test through d-c machines, are given by curve *D*.[4] Values as determined by the d-c excitation method[2] are also given for comparison in curve *E*. The results shown by curves *B*, *D*, and *E* were given in a previous paper[4] and are repeated here so that the curve *A* determined by the reverse-rotation method may be compared with them.

The curves of figure 2 show that for motor 1 the reverse-rotation method gives values for the stray load loss that are in as close agreement with those from other methods of testing as exists among the other methods themselves. At the full-load point the reverse-rotation method value is only 7 watts above the highly accurate value obtained by loading back through d-c machines, and 14 watts above the result obtained by the belted load-back method. At 125 per cent load the values from curve *A* and curve *B* agree almost exactly. The reverse rotation method gives a value that is about 11 watts high at 50 per cent load.

Motor 2

This motor differed from motor 1 in that it possessed abnormally high iron losses, being 5.0 per cent for this machine as compared with 2.9 per cent for the first motor. It was also of the squirrel-cage type and was rated 10 horsepower, 220/440 volts, 26.6/13.3 amperes, 3 phase, 60 cycles, 1,710 rpm. It was tested for stray load losses by three different methods of testing: the reverse rotation, the belted load-back,[3] and the d-c excitation method.[2] The test points of the reverse rotation method are shown by curve *F* in figure 3, plotted to logarithmic scales, and again give a straight line having a slope of two. Straight line extension downward is shown by a dashed line as before while the dotted line shows extension after the application of the light load correction. The results of the belted load-back test are shown by curve *G*, while curve *I* gives results of this test with the no-load component included.

The results of the three tests over the normal operating range of the motor are shown in figure 4, where curve *F* is determined by the reverse-rotation method, (the dotted line showing corrected curve for light loads), curve *G* comes from the belted load-back test, and curve *H* is derived by application of the d-c excitation method. At the full-load point curve *F* lies approximately midway between curves *G* and *H* being about 23 watts above the belted load-back method value and 24 watts below the value obtained by the d-c excitation method. At 125 per cent load curves *F* and *G* agree and curve *H* is 30 watts higher. The reverse-rotation method gives a value that is about 7 watts higher than that from the belted load-back method at 50 per cent load, and it is about the same amount below the d-c excitation value in this region.

Because of difficulties involved in performing the tests and inaccuracies inherent in each method, complete agreement in results by application of the various methods employed has not been possible. However, the reverse-rotation method has given results for the two motors tested that are well within the degree of accuracy which might be expected from any of the methods used.

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2. Measurement of Stray Load Loss in Polyphase Induction Motors, **C. J. Koch.** AIEE Transactions, volume 51, 1933, pages 756–63.

3. Stray Load Loss Test on Induction Machines, **T. H. Morgan** and **Paul M. Narbutovskih.** AIEE Transactions, volume 53, 1934, pages 286–90.

4. Stray Load Loss Tests on Induction Machines—II, **T. H. Morgan** and **Victor Siegfried.** AIEE Transactions, volume 55, 1936, pages 493–7.

5. Efficiency Tests of Induction Machines, **C. C. Leader** and **F. D. Phillips.** AIEE Transactions, volume 53, 1934, pages 1628–33.

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Discussion

L. E. Hildebrand (General Electric Company, Lynn, Mass.): It is known that stray load loss causes the speed-torque curve to depart appreciably from the calculated curve predicted by formulas which do not take high-frequency core loss into account. These losses constitute a part of the load on the motor and hence must reduce the net torque at a given forward speed and increase the gross torque at any backward speed. It should be possible to predict the correction in torque at any speed by an extrapolation of the stray load loss measured at normal speed and load. We have made fairly accurate predictions with quite simple assumptions for extrapolation, namely, high-frequency loss proportional to rotor current squared and frequency to the three-halves power. Agreement at backward speeds and at speeds greater than half forward speed are very good.

The converse is also true, that is, from tested backward rotation torque or tested breakdown torque we can find out what the stray load loss at normal load and speed is. We have used (1) backward rotation, (2) d-c excitation, (3) polyphase breakdown torque, and (4) single-phase breakdown torque, all to measure stray load loss. All agree quite well. Measurement of the single-phase breakdown torque seems to be a very good alternative method to d-c excitation and backward rotation.

William R. Hough (Reliance Electric and Engineering Company, Cleveland, Ohio): The paper under consideration presents a method of study of the stray load losses of induction machines, which is a definite contribution to progress in this field. This discussion is based on a limited experience with the method developed by the authors.

This limited experience has shown that of the advantages claimed by the authors for their method of testing, the degree of accuracy is the only point in question. The tests are simple and convenient to perform, can be done relatively quickly with a minimum of necessary equipment, and the computations of stray load loss from test information are not laborious.

An analysis of the steps taken in arriving at the value of stray load loss for a particular condition readily indicates that a high degree of accuracy is necessary in each test reading obtained, in order that the final result, namely, stray load loss, will be accurate.

The stray load loss is the difference between two quantities, each of which is the difference between two other quantities. In testing a normal induction motor having from one to two per cent stray load loss, it will be found that the stray load loss is

small in comparison with the test values obtained by this method from which it is determined. In testing machines having higher than normal stray load losses, the relative accuracy should be greater, since the stray load loss for any condition would be larger in comparison with the values from which it is obtained.

The authors have pointed out that their method neglects one of the components of stray load loss, and have cited certain compensating items. They have not attempted to evaluate these discrepancies other than to demonstrate that their method gives substantially accurate results by actual test in comparison with load-back test results. The final proof by actual test results is, of course, the most important consideration in determining the value of this method of testing. The authors have, by the limitations they have cited, pointed out the necessity of proof of the method of actual test results, and have contributed two specific cases to support this proof.

The limited number of tests which are the basis of this discussion substantiate the method in principle, but do not substantiate the degree of accuracy obtained by the authors. Present experience would indicate the variance between the values of stray load losses determined by this method and those determined by load-back tests, to be in the order of one per cent of motor input. Continued experience is necessary before a more accurate opinion can be given.

P. C. Smith (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): This is the least complicated method so far proposed for squirrel-cage motors. It has no advantage, from a simplicity standpoint, over the Koch method for wound-rotor motors, since the same readings are required for both. The authors have pointed out the errors in principle and the assumptions made in this method and show by test that they are negligible or are compensated for in a ten-horsepower four-pole motor. There are, however, two factors which are increasingly important with increase in motor size and, if neglected, will lead to appreciable error. I have reference to the fundamental end-zone loss and the correction for magnetizing current at full load.

In large motors, particularly high speed, the end-zone loss is an appreciable amount. When the input to the stator is measured, this loss is included. Hence, when stator input is subtracted from rotor input, this end-zone loss serves to reduce the net result when actually it should be added. That is, twice the end-zone loss must be added to the answer obtained by this method to get the correct loss. This loss is partly compensated by neglect of the magnetizing current, but it does not necessarily follow that they balance. In fact, in large high-speed motors, it may lead to considerable error.

It is pointed out in the paper that the absence of magnetizing current, rather the fact that it is low, results in a secondary current which is too high. In low-speed motors, where the magnetizing current is large, some correction at full load will be necessary.

As pointed out in this discussion, this loss and the end-zone loss tend to balance, but the high end-zone loss goes with high-speed motors while high magnetizing current goes with slow speed and only in certain cases will they cancel out.

Further tests, over a wide range of horsepower and speed, are required to check this method.

R. E. Hellmund (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): After listening to the paper by Morgan, Brown, and Schumer and some of the discussions, I believe that in view of the widely different results obtained, better progress could be made in evaluating the various methods under discussion if more data were given regarding some of the important design characteristics of the machines tested. At least it would be desirable to know the speeds, ratings, and various essential facts regarding the slot, tooth, and tooth-tip structures. If some such data were available, it might be possible to draw conclusions as to which of several methods can be used to best advantage for a given range of sizes or types of motors. Undoubtedly it is desirable to find methods giving satisfactory results for all ratings, but such ideal conditions cannot always be obtained and therefore it may be necessary to exercise a certain amount of discrimination.

C. J. Koch (General Electric Company, Schenectady, N. Y.): The test described in this paper is the easiest to perform with accuracy, of the methods so far developed for measuring the stray load loss of induction machines. In short the test procedure itself and the apparatus required become identical with the established short-circuit core-loss test of synchronous machines of similar sizes.

Does the reverse-rotation test determine the value of the stray load loss as it actually exists in the machine under load conditions? If we could calculate accurately the high-frequency core and stray load losses in induction machines this question could be answered from theoretical considerations. This we cannot do, however, and we must resort therefore to tests of large numbers of motors to determine the importance of the disturbing effects mentioned by the authors.

The result of our experience has been that these effects are small. This indicates the principle source of the high-frequency losses to be the action of the tooth harmonic fluxes. As far as the action of the stator-tooth harmonic fluxes on the rotor is concerned their frequency is very nearly the same for normal operation, reverse-rotation test, or normal-speed test with d-c applied to the stator. We have to offer one test confirming this. The motor tested was rated 150 horsepower, 900 rpm, and was of the collector ring type. At rated load the values are:

Stray load loss by pump-back between identical motors	615 watts
Stray load loss by reverse-rotation test	600 watts
Stray load loss by d-c excitation of rotor	600 watts

We have also measured the stray load loss of a number of motors by the reverse-rotation test and by very carefully made dynamometer tests. All of these motors were rated 25 horsepower at 1,800 rpm synchronous speed and were of the squirrel-cage type. The results are shown in table I of this discussion. It will be noted that the stray load loss varied greatly from motor to motor. The reverse-rotation test, however, follows the dynamometer result with very satisfactory agreement at rated load.

Table I

Motor	Stray Load Loss by Dynamometer (Watts)	Stray Load Loss by Reverse Rotation (Watts)
A	637	650
B	230	245
C	400	335
D	195	230
E	487	450
F	712	620
G	130	215
H	1,003	800
I	355	520
J	747	670
K	224	350
L	184	157
M	255	260

These results create confidence in the reverse-rotation test as a measure of stray load loss. The ease of making the test and the fact that one motor only is required should stimulate further testing along this line with the ultimate object of incorporating the reverse-rotation test in the test code.

F. D. Phillips (General Electric Company, Schenectady, N. Y.): The data given in this paper show a very good agreement between the various methods of determining the stray load losses. For the first machine these are, reading from figure 2,

By reverse-rotation method	194 watts
By load-back through belt	180 watts
By load-back through d-c machines	187 watts
By d-c excitation of stator	165 watts

A maximum difference of 29 watts and a variation from the average of 17 watts.

For the second machine the results obtained are, reading from figure 4,

By reverse-rotation method	270 watts
By load-back through belt	247 watts
By load-back through d-c machines	294 watts

The maximum difference is 47 watts and the variation from the average 24 watts.

The accuracy of the determination of these losses is apparent when we realize that a number of instruments are used and careful investigation has shown that on such tests the best accuracy of the instruments and of observation is in the neighborhood of 30 watts under carefully controlled laboratory conditions.

The results shown in Mr. Koch's discussion of a larger number of comparisons between the reverse-rotation method and the dynamometer method show a fair agreement. The difference between the two methods varies from 5 to 37 watts in seven cases and from 65 to 203 watts in six cases and the machines on which one method gives lower losses are the same in number as those which gave higher losses. These tests were taken under commercial factory conditions and the results would not be expected to be as accurate as those obtained in a laboratory.

The results given in this paper and the discussion lead to the belief that further study will confirm the validity of this testing method. It is attractive because of its simplicity and because it does not require special apparatus, and the calculation of the results is simple.

Q. Graham (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): Mr. Morgan and his associates have proposed an ingenious method of measuring stray load losses which has a fairly sound theoretical basis. There is a definite need for such a method, particularly for larger motors where other methods of testing are more difficult. The accuracy of the method, however, must be checked with smaller motors for which input-output tests are possible.

I have applied the reverse-rotation test to six motors ranging in size from 3 to 20 horsepower. The stray loss is given in table II of this discussion for 100 per cent and 125 per cent current and is compared with the loss by input-output test. For four of the six motors the reverse-rotation test shows about double the loss given by input-output test while for the other two there is close agreement although the reverse-rotation method still shows the higher values. For the last motor on the list the losses by input-output test were measured at a reduced voltage also and it was found that for the same values of current the stray loss was higher, thus more nearly approaching the loss measured by reverse rotation. This would seem to indicate that the presence of normal saturation may have a more important effect than the authors have assumed and may account for much of the discrepancy shown by these tests. The authors, of course, have a right to question the accuracy of the input-output tests which have been used for comparison in the results presented here. I can only say that they are the result of a great deal of painstaking work in perfecting a testing procedure in which we ourselves have considerable faith. The comparative tests are an honest attempt to judge the merits of the proposed method but are by no means presented as final evidence of its failure.

Victor Siegfried (Worcester Polytechnic Institute, Worcester, Mass.): The authors are to be commended on the development of a method which is simple and is performed with the most fundamental equipment. Having had experience in some of the previous work on one of these same machines in which the stray load loss was determined by loading-back tests, I can confirm the claims made for this present test as to the ease with which it is performed. The relative amounts of time consumed in the two tests are illustrated by the fact that a whole run was made and calculated up into final results in about the same time required for one point in the previous tests. It is further interesting to note that all that is required in this new method is some machine to drive the motor at synchronous speed backward and a source of reduced potential at rated frequency, in the order of 20 per cent of the original ratings of the machine on test, depending upon its constants.

The test itself is particularly noteworthy in that it measures the losses of the machine under conditions of loading although at reduced excitation, and the separation of these losses is very simple as outlined in the body of the paper. This gives a test whose final results for stray load loss are substantially in agreement with other tests of proved accuracy, and even though there are inherent errors in the method, the authors have logically demonstrated that these errors tend to compensate for each other.

T. H. Morgan: The discussion on this paper is on the whole encouraging. In considering a test method of this kind it would be unfortunate if it were to meet with complete approval before receiving the necessary verification covering a complete range in machine type and size. The fact that several tests have already been made and reported on in the discussions indicates interest in the matter. It is our hope that this interest will continue so that the limitations of the test and its degree of accuracy may be definitely established.

It is the authors' opinion that the industry possesses too little knowledge regarding these losses, both as to the mechanism that produces them, and their exact location in the machine. As an example, P. C. Smith believes that an end-zone loss takes place in the stator of large high-speed motors, thus decidedly limiting the accuracy of the method described; that if this end-zone loss is an appreciable amount of the total stray load loss, the proposed treatment would produce a result considerably too low in amount. This reasoning seems correct. On the other hand, the results obtained by Q. Graham would indicate that the reverse-rotation method gives a value of loss which is high in all cases of motors of two poles tested by him. There are several similar conflicting differences embodied in the discussion and this one is mentioned only to illustrate the point that as yet we do not know which view is the correct one. The discussion indicates the need of a better understanding of the nature of stray load loss if we are to make progress in reducing it by improvement in design.

The apparent lack of agreement between the results of tests made by different people to determine the accuracy of the proposed method is not surprising. The experience of the authors has been that it is very difficult to secure the same measured value of the loss from any two of the recognized standard methods of testing. Those who work on the problem of stray-load-loss measurement will always agree on one point—namely, the difficulty of making accurate determinations. It therefore seems hardly sufficient to compare the results of the reverse-rotation test with values obtained by only one other method. It takes more time and energy to use several methods but a much more accurate comparison will result. In this connection the test results obtained by C. J. Koch on the 150-horsepower, 900-rpm motor are encouraging.

The suggestion of R. E. Hellmund that design information be given whenever possible is well taken. Only through a large number of tests on motors of different design will it be possible to determine the limiting point where a new method of testing fails to give sufficiently accurate results. It is quite possible that any one method may apply to only a certain range in size and type of motors. If so it would be advantageous to know the limitations. Design data regarding motor number 1 of the paper were previously given in reference 4. Exact design details of the other motor are not known but it can be said that they are similar in character.

The remarks of L. E. Hildebrand regarding the application of the laws of variation of stray load loss as a function of current and speed are pertinent. The authors have made investigations of these effects over the complete range of reverse rotation of the motor, and plan to have their findings ready for publication in the near future.

In closing the discussion it should be again pointed out that the authors feel that while the general results from the limited number of tests taken to date indicate possible high accuracy for the reverse-rotation method of testing, many more tests should be made employing different methods of testing before a satisfactory conclusion can be reached.

Table II

Motor Number	Horsepower	Poles	Per Cent Current	Watts Stray Load Loss: Input-Output	Watts Stray Load Loss: Reverse Rotation	Watts Stray Load Loss: Direct Current (Code)
1	7½	2	100	225	500	
			125	400	720	
2	7½	2	100	240	425	375
			125	405	620	600
3	20	2	100	355	790	
			125	700	1,220	
4	7½	4	100	135	145	160
			125	205	220	239
5	15	4	100	415	495	
			125	615	785	
6	3	2	100	35	90	220 volts
			125	62	142	220 volts
6	3	2	*100	50	90	180 volts
			*125	89	142	180 volts

* Losses recorded are for same amperes as for 220-volt test.

Inductive Co-ordination With Series Sodium Highway Lighting Circuits

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Synopsis: This paper describes the wave-shape characteristics of the sodium-vapor lamp and discusses the relative inductive influence of various series circuit arrangements in which such lamps are employed. A method is outlined by means of which the noise to be expected in an exposed telephone line may be estimated. Measures are described which may be applied in the telephone plant or in the lighting circuit to assist in the inductive co-ordination of the two systems. These measures need be considered only when a considerable number of lamps is involved, since noise induction is negligible when there are only a few lamps as, for instance, at highway intersections.

DURING the past few years, a new type of lamp has been developed for highway lighting purposes, making use of ionized sodium vapor as its luminous element. While lamps of this type can be operated in parallel, the most common application has been in the conventional series types of lighting circuits supplied through constant-current transformers.

The wave-shape characteristics of sodium-vapor lamps are such that where series lighting circuits supplying a considerable number of such lamps are involved in exposures with open-wire telephone lines, attention must be given to the co-ordination of the two systems from the noise standpoint. The present paper gives the results of an investigation of the various factors involved in situations of this character. It is based largely upon a study conducted by project committee 1*A*, on noise induction, of the Joint Subcommittee on Development and Research of the Edison Electric Institute and the Bell Telephone System.

The wave-shape data included herein were obtained in the laboratory of one of the manufacturers and, through the co-operation of one of the power companies, on a number of field installations of sodium lamps of the same manufacturer. One of the situations tested, in which a lighting circuit some 16 miles in length was involved in an exposure with an open-wire telephone toll line, afforded an opportunity for co-ordinated inductive influence and noise measurements.

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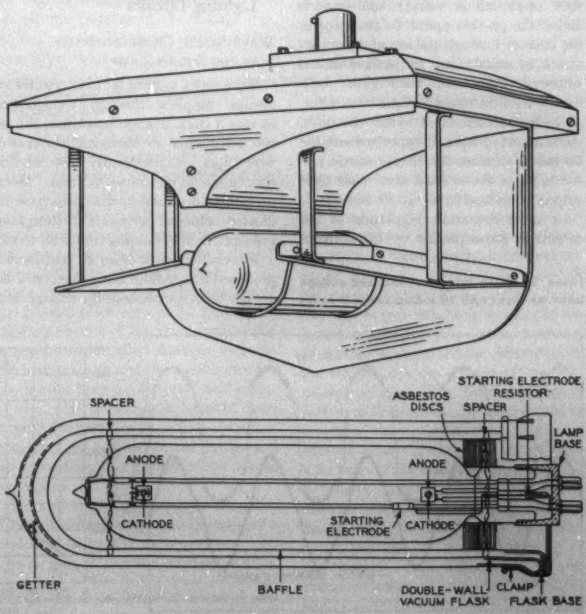
1. For all numbered references, see list at end of paper.

Operation of Sodium-Vapor Lamps

A brief review of the construction and operation of the sodium-vapor lamp[1,2] may be of interest as a preface to the wave-shape discussion which follows. The essential details of the sodium lamp designs of two of the manufacturers, together with sketches of the luminaires in which they are mounted, are shown in figures 1 and 2. The following is a brief description of the lamp shown in figure 1.

The lamp consists of a long evacuated glass bulb enclosing, at each end, a tungsten filament or cathode and an open-end molybdenum anode. Each anode is connected to one side of the adjoining filament, the leads to the latter passing through a seal at one end of the bulb to a four-prong tube base which, in turn, makes contact with the socket. The luminous arc occurs between the anode at one end of the tube and the cathode at the opposite end. The connections are so arranged that the two anode-cathode combinations function alternately as the sign of the impressed voltage becomes alternately positive and negative. As indicated in figure 1, the anode-cathode assemblies are symmetrically located in the tube. Differences which occur between the positive and negative portions of the arc voltage curve in a particular lamp, as discussed hereinafter, are therefore due to vagaries of the arc rather than mechanical dissymmetries in the lamp. The bulb is insulated from the outside air by an evacuated glass bottle similar to a Dewar flask. The flask is required to retain heat generated by the arc for vaporizing sodium, which is solid at room temperature. Co-ordinated designs of flask and lamp are required to minimize the effects of external temperatures on the tempera-

Figure 1. Ten thousand-lumen sodium lamp and luminaire—manufacturer A



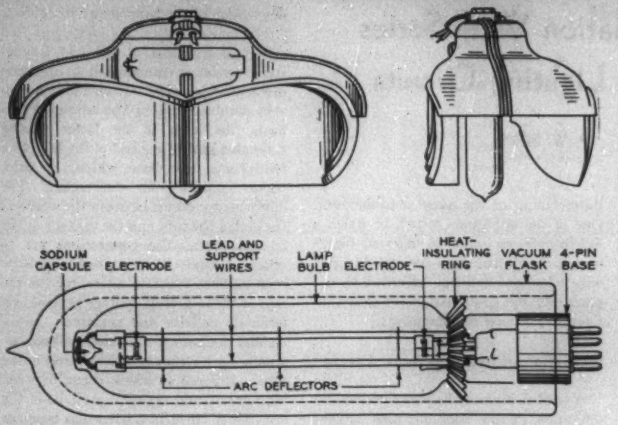


Figure 2. Ten thousand-lumen sodium lamp and luminaire—manufacturer B

ture within the lamp, and consequently on the light which is produced. Neon at a few millimeters pressure (for starting) is included in the bulb.

During the first few seconds after a lamp of this type is energized, the anodes are short-circuited by a time relay. During this period the normal current of 6.6 amperes is passed through the two filaments in series providing a degree of preheating. The short-circuiting contacts then open and a voltage sufficient to ionize the gas is applied to the anodes, the current through the arc and the filaments in series being maintained at 6.6 amperes. The lamp then glows brilliantly with the characteristic neon color. As heat is accumulated within the bulb, the sodium is gradually vaporized and the discharge acquires the characteristic yellow color of the sodium arc. Full light output is reached in about 30 minutes.

In series operation, regulation of the current is accomplished by the conventional constant-current transformer which has a relatively high leakage reactance. In multiple-circuit operation this regulation is effected by means of a special high-leakage-reactance transformer located in or near the luminaire.

Inductive Influence of Series Lighting Circuits

Wave-Shape Characteristics of the Sodium Lamp

Since series sodium lighting circuits are always supplied through transformers having a high leakage reactance, the series impedance to harmonic currents is very high. Consequently the current wave approaches sinusoidal form. Measurements on several installations have indicated values of current TIF (telephone influence factor) ranging from four to ten.

It is characteristic of an arc such as that produced in a sodium lamp that, once the arc has been established, the voltage drop tends to be constant irrespective of the current. This gives rise to a flat-topped voltage wave, more nearly square than sinusoidal in form. This is illustrated by the oscillogram in figure 3, which was taken on a circuit employing 18 sodium lamps in series.

A harmonic analysis of the voltage wave across a single sodium lamp is given in the second column of table I. Only harmonic components in the range up to 1,500 cycles are listed although the measurements indicated the presence of a practically continuous band of harmonic frequencies extending well above 3,000 cycles. The magnitudes of the various harmonics, particularly those at the higher frequencies, varied over a considerable range from time to time. The figures in the table represent average values observed over a relatively short interval. It will be noted that many of the even as well as the odd harmonics were present, indicating that the positive and negative halves of the voltage wave were not exactly alike. In the case of this particular lamp, some of the higher even harmonics were at times, larger than the adjacent odd harmonics and controlled the voltage TIF.

In a series sodium lighting circuit the various lamps can be considered as serially connected harmonic generators. The equivalent series reactance of the supply transformer is high compared to the impedance of the lighting circuit including the lamps. Furthermore, in circuits of the lengths under consideration, attenuation and phase shift are not important. If all lamps were identical, therefore, the per cent harmonic voltages and the voltage TIF at the supply end of a long circuit would be the same as for a single lamp. The $Kv \cdot T$ (kilovolts $\times$ voltage TIF) would be equal to that for a single lamp multiplied by the number of lamps.

Figure 3. Wave form of current and voltage taken on circuit with 18 sodium lamps in series

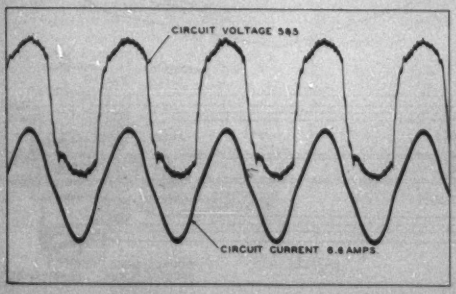
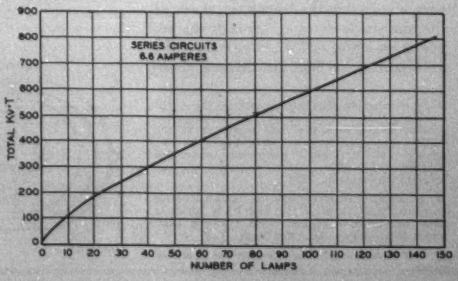


Figure 4. Total Kv·T for sodium lighting circuits having various numbers of lamps



The fourth column of table I gives a harmonic analysis of the voltage as observed at the supply end of a series lighting circuit comprising 149 lamps. In general, the odd harmonic voltages (in per cent) observed on the long circuit are somewhat smaller than those measured on a single lamp, indicating some differences in the relative magnitudes and phases of the odd harmonics generated in the individual lamps. The even harmonics are greatly reduced in the long circuit and are not important contributors to the voltage TIF. This indicates that the even harmonics generated in the individual lamps are fortuitous in character, tending to cancel when a number of lamps are connected in series. Additional data taken on operating circuits of various lengths and showing the variation of the total $Kv \cdot T$ with the number of lamps in series have been plotted giving the curve shown in figure 4.

Distribution of Balanced Kv·T Along the Circuit

Since each lamp of a series circuit acts as a serially connected generator of harmonic voltages, the $Kv \cdot T$ across the circuit changes at each lamp, decreasing progressively from a maximum at the supply end to the value for a single lamp at the distant end of the circuit. While no experimental data are available on the rate of change in the influence, it is probable that a plot of the influence against distance from the far end of the circuit would have a shape similar to the curve in figure 4. In estimates of noise in the practical case, however, a straight-line variation is usually assumed.

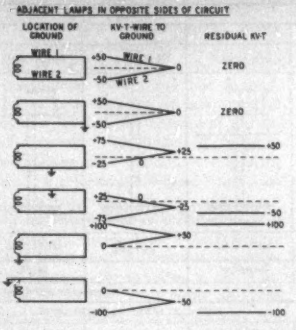
It has been found that the leakage reactance of the constant-current transformers used to supply series circuits of this type is usually sufficiently high to prevent the transfer of the voltage distortion from the lighting circuit back into the supply circuit.

Table I. Analyses of Voltage on Sodium Lighting Circuits

Frequency	Single Lamp Current = 6.6 Amperes. Root-Mean-Square Voltage = 30 Volts — Per Cent of Root Mean Square	Single Lamp Current = 6.6 Amperes. Root-Mean-Square Voltage = 30 Volts — TIF	Series Circuit, 149 Lamps Current = 6.6 Amperes. Root-Mean-Square Voltage = 4,850 Volts — Per Cent of Root Mean Square	Series Circuit, 149 Lamps Current = 6.6 Amperes. Root-Mean-Square Voltage = 4,850 Volts — TIF
120	*	*	*	*
180	21.9	3	13.9	2
240	*	*	*	*
300	12.9	27	8.7	18
360	*	*	*	*
420	6.1	36	4.2	25
480	*	*	0.6	5
540	2.55	32	3.18	40
600	*	*	0.54	9
660	0.53	12	2.70	61
720	1.82	54	0.43	13
780	1.98	81	1.82	74
840	1.98	109	0.33	15
900	0.83	60	0.61	44
960	1.66	156	0.20	19
1,020	0.41	48	0.14	16
1,080	1.66	199	0.14	17
1,140	0.99	110	0.54	60
1,200	1.82	173	0.17	16
1,260	0.73	58	0.62	49
1,320	0.64	42	0.15	10
1,380	2.12	116	0.80	44
1,440	0.89	42	0.18	9
1,500	1.16	51	0.52	23
TIF	500-625	400**	166.	155**
$Kv \cdot T$	15.3-17.4		805.	

* Value measured controlled by adjacent harmonics or "background."

** TIF calculated from analysis up to 1,500 cycles.



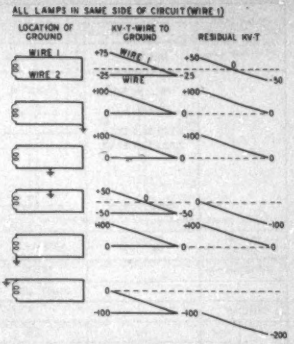


Figure 5. Distribution of Kv·T along a series sodium lighting circuit

Assumptions: capacitance and leakage to ground of the two wires the same; all lamps of identical characteristics

Note: Numerical values indicate percentages of $Kv \cdot T$ at transformer terminals

Magnitude and Distribution of Residual Kv·T

In the case of a single-wire ground-return circuit, the residual $Kv \cdot T$ at any point is, of course, the total $Kv \cdot T$ of the circuit at that point.

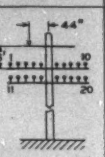
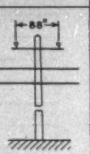
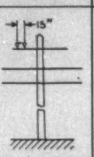
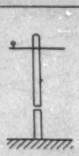
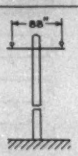
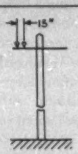
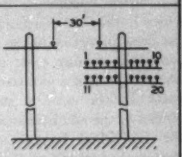
On a two-wire circuit where both wires are on the same pole line, the magnitude and distribution of the residual voltage† depend upon the number of lamps, the location of the lamps, and the location of any ground which may be on the circuit. Lighting circuits of the usual lengths are in general electrically short so that the series impedances and the capacitance between wires have a relatively small effect. In the case of a circuit isolated from ground, the voltages to ground are determined by the location of the lamps and the capacitances to ground of the circuit conductors.

Figure 5 shows schematically a number of circuit arrangements and indicates the variation, along the circuit, of the voltages to ground and the residual voltage.

† Vector sum of the voltages to ground of each wire.

The smooth variations in these quantities shown in this figure would occur only for lamps extremely close together. In practice there is, of course, an appreciable distance between lamps, and the curves under such conditions consist of a series of steps, the influence being constant over each interval between lamps. The diagrams in figure 5, also involve the assumption that the wave-shape characteristics of all the lamps are identical.

It is evident from figure 5 that the lowest residual voltage occurs where the lamps are staggered, that is where adjacent lamps are in opposite sides of the circuit, and where the circuit is ungrounded or grounded at a balanced point only. For a large number of lamps spaced at finite distances and arranged as above, the residual voltage in each interval between lamps is, theoretically, one-half the voltage generated by a given lamp. The sign of this voltage is opposite in adjacent intervals. In practice, however, there may be considerable differences in the magnitudes and phases of the harmonics resulting from different lamps as well as differences in the capacitance to ground of the two wires (due to the presence of other conductors, etc.) or even differences in the leakance of the two wires to ground. The theoretical reductions in residual voltage due to staggering the lamps, therefore, may not be fully realized. In one case tested, involving an ungrounded circuit 6.6 miles long with staggered lamps, the residual $Kv \cdot T$ at the supply end was found to be about 13 per

INDUCTION FROM RESIDUAL OR BALANCED VOLTAGE →	CASE						
	1	2	3	4	5	6	7
	RESIDUAL	BALANCED	BALANCED	RESIDUAL	BALANCED	BALANCED	BALANCED
							
LIGHTING CIRCUIT →	GROUND RETURN	METALLIC	METALLIC	GROUND RETURN	METALLIC	METALLIC	METALLIC
SPACING →		WIDE	NARROW		WIDE	NARROW	WIRES AT ROADWAY SPACING
	JOINT USE			ROADWAY SEPARATION **			JOINT USE AND ROADWAY
CIRCUIT	METALLIC NOISE IN NOISE UNITS						
SIDE 1–2	70	24	17				
SIDE 3–4	2	16	8				
SIDE 5–6	55	55	6				
SIDE 7–8	30	16	2				
SIDE 9–10	25	24	2				
PHANTOM 1–4	200	100	46	105	12	5	50
PHANTOM 7–10	4	100	0	12	1	0.5	8
PHANTOM 5–18	230	0	24	60	7	3	90
	LONGITUDINAL NOISE IN NOISE UNITS						
SIGMA 1–20	14	0	0.4	2.5	0.3	0.2	6

* FOR 2-WIRE CIRCUIT, BALANCED KV·T BETWEEN WIRES; FOR GROUND RETURN CIRCUIT, RESIDUAL KV·T FROM WIRE TO GROUND

** 30-FOOT SEPARATION BETWEEN TELEPHONE AND LIGHTING CIRCUIT WIRES, WITH GROUPS 1–4 NEAREST LIGHTING CIRCUIT

Figure 6. Calculated noise induction in untransposed telephone circuits exposed to a series sodium lighting circuit

cent of the balanced $K_V \cdot T$. While direct measurements of the residual voltages were not made at other points along the line, tests under various grounding conditions indicated that the distribution of the residual $K_V \cdot T$ was similar to that shown in the upper right-hand diagram of figure 5. A comparison of the value of 50 per cent for residual $K_V \cdot T$ shown in this diagram (for lamps all in one side of the circuit) with the measured value of 13 per cent indicates a four-to-one reduction in the maximum value obtained by the staggered arrangement of lamps. The net effect is small near the center of the line, since the residual $K_V \cdot T$ approaches zero for either lamp arrangement.

As indicated in figure 5, when the lamps are staggered, the presence of a ground at any point other than at the far end of a series circuit (or at the midpoint of the supply transformer) greatly increases the residual voltage. A practical example of such an effect was experienced in one situation where an accidental ground on one side of a six-mile lighting circuit increased the phantom-circuit noise on an exposed telephone toll line from about 400 noise units to the order of 2,000 noise units.

In some cases lighting loops are laid out on an all-metallic basis but with the outgoing and return wires quite widely separated. Near the supply end of either the outgoing or the return wire, the residual voltage (on one wire), for a circuit having the lights uniformly spaced, is about half the total voltage across the transformer. This may be seen by a reference to the upper figure in the left-hand column of figure 5. The residual $K_V \cdot T$ is, in this case, the $K_V \cdot T$ to ground on the particular wire involved.

Inductive Coupling

Since distortion of the current wave form is not an important factor in the coordination of series sodium lighting circuits and exposed telephone circuits, no consideration need be given to magnetic induction from the load current. Furthermore, since the length of circuit is relatively short, the effect of the ground-return charging current resulting from the action of residual $K_V \cdot T$ can usually be neglected, especially if the circuit is reasonably well balanced to ground. Noise resulting from electric induction from the harmonic voltages on the lighting circuit is, therefore, the only component of importance. It depends upon the relative magnitudes of the balanced and residual $K_V \cdot T$, the configuration of the exposure, and the number and locations of telephone circuit transpositions.

If either circuit is in metallic-sheathed cable, the shielding effect of the sheath practically eliminates the induction.

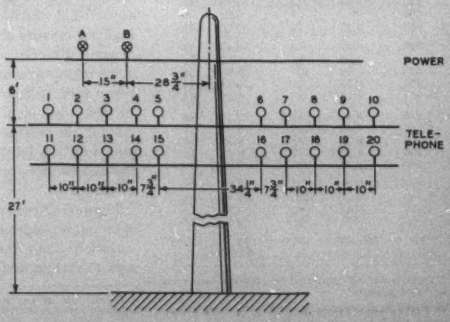
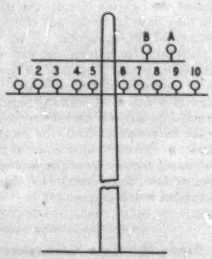


Figure 7. Exposure configuration

Exposure Configuration

In order to indicate the relative influence of various configurations, calculations have been made of the noise induction for a one-kilofoot uniform section of exposure, in which the average lighting circuit $Kv \cdot T$ was taken as 100 and throughout which the telephone circuits were assumed untransposed. These noise induction data are shown in figure 6. The noise-metallic values are for a circuit terminated at each end in its characteristic impedance. The noise-longitudinal values are totals, and will divide in the two directions from the exposure inversely as the respective longitudinal circuit impedances.



$N_{nA} = 0.1 \cdot C_{nA} \cdot Kf \cdot Kvg_A \cdot T$ NOISE UNITS

$N_{nB} = 0.1 \cdot C_{nB} \cdot Kf \cdot Kvg_B \cdot T$ NOISE UNITS

$N_n = N_{nA} + N_{nB}$ NOISE UNITS

$N_{MS} = 0.25\,(N_a - N_b)$ NOISE UNITS

$N_{MPh} = 0.2\,[(N_a + N_b) - (N_c + N_d)]$ NOISE UNITS

$N_L = 0.5\,(N_a + N_b) \cdot 10^{-3}$ NOISE UNITS

N_{nA}—Noise current in telephone wire n due to induction from voltage to ground of lighting-circuit wire A

N_n—Total noise current in telephone wire n due to induction from voltage to ground of both lighting-circuit wires A and B

N_{MS}—Metallic-circuit noise in side circuit terminated in its characteristic impedance (N_{MPh} same for phantom circuit)

N_L—Noise-longitudinal per wire

C_{nA}—Direct capacitance between wire n and wire A, micromicrofarads per kilofoot

K_f—Length in kilofeet of section of uniform configuration

$Kvg_A \cdot T$—Average value, in a section of uniform configuration, of product of voltage to ground of wire A in kilovolts and its TIF

a, b, c, d—Subscript letters indicating the four wires of a phantom circuit, as 1, 2, 3, 4 or 7, 8, 9, 10

Figure 8. Formulas for estimating noise in open-wire telephone circuits in joint use with a series sodium lighting circuit

(Applying to sections of uniform configuration)

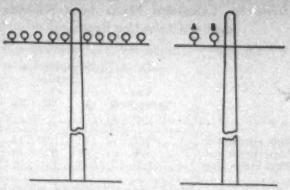
The advantage of a closely spaced all-metallic circuit with staggered lamps over a ground-return lighting circuit, at joint-use separations, may be observed by comparing cases 1 and 3 of figure 6. These figures indicate an advantage of between 5:1 and 10:1 in favor of the metallic circuit. This applies, of course, to the average noise conditions across the lead. A comparison of cases 2 and 3 indicates that, except for longitudinal circuit induction, most of the advantage of the metallic circuit is lost if the two wires are widely separated on the crossarm. The figures given for cases 2 and 3 assume the residual $Kv \cdot T$ to be negligible due to the staggering of the lamps. If a residual $Kv \cdot T$ of ten per cent of the $Kv \cdot T$ between wires were assumed, the figures for case 3 would be increased, on an average, by about ten per cent. However, this would not greatly decrease the advantage of the two-wire balanced circuit over the ground-return arrangement.

At roadway separation the data of figure 6 show the two-wire closely spaced arrangement (case 6) to compare even more favorably with the ground-return circuit (case 4). Even the wide-spaced two-wire circuit (case 5) has a decided advantage over the ground-return circuit at a 35-foot separation. Here again the figures given for the two-wire circuits at roadway separation neglect the effects of residual voltage. If a residual $Kv \cdot T$ of ten per cent were assumed, the figures for case 6 at roadway separation would be increased in a ratio of about 2:1. However, the advantage in favor of the two-wire narrow-spaced circuit as compared to the ground-return circuit would still be of the order of 10:1.

A two-wire arrangement in which one wire is located on each side of the road (case 7) is about equivalent, from the noise standpoint, to a ground-return circuit located across the road from the telephone line.

Telephone Circuit Transpositions

Telephone circuit transposition systems are of maximum effectiveness when (1) the power circuit influence is constant throughout the exposure, (2) the exposure configuration is uniform, and (3) neutral points in the telephone transposition layout occur at the ends of the individual exposure zones. In the case of exposures to series sodium lighting circuits, there is a continuous variation in influence from a maximum at one end to zero at the other end of the lighting circuit. However, if the second and third conditions just mentioned are realized, the variation in influence may not seriously impair the transposition effectiveness. This is because the unneutralized induction in one portion of a transposed section will generally be opposed by that in a succeeding portion. The length of section in which this takes place depends upon the transposition system and also upon the particular circuit under consideration. Thus in the exposed line system,[3] neutralization takes place between successive eight points for side circuit 1–2, while for side circuit 3–4 a half section is required. On the other hand, in the K-8 phantomed system the transposition pattern is more complex and such simple relations do not hold. This effect is illustrated by the calculated values of noise given in table II for idealized exposure conditions. A uniform joint-use exposure, having the configuration shown in figure 7, was assumed between a 6.5-mile ungrounded lighting circuit and a 20-wire telephone line. The influence of the lighting circuit was assumed balanced with the $Kv \cdot T$ varying uniformly from



$N_{ab} = 0.1 \cdot C \cdot K_f \cdot Kv \cdot T$ noise units

$N_{MPh} = 0.2\,(N_{ab} - N_{cd})$ noise units

N_{ab}—Longitudinal noise current in telephone pair ab due to induction from lighting circuit voltage*

N_{MPh}—Metallic-circuit noise in phantom circuit terminated in its characteristic impedance

C—Longitudinal circuit coupling capacitance* between a telephone pair and the lighting circuit—micromicrofarads per kilofoot

$Kv \cdot T$—Average value, in a section of uniform configuration, of product of lighting-circuit voltage* and its TIF

a, b, c, d—Subscript letters, indicating the four wires of a phantom circuit, as 1, 2, 3, 4 or 7, 8, 9, 10

K_f—Length in kilofeet of section of uniform configuration

*Note: If lighting circuit is unbalanced to ground, carry through computations both for balanced and residual voltage

Figure 9. Formulas for estimating noise in open-wire telephone phantom circuits exposed at highway separation to a series sodium lighting circuit

(Applying to sections of uniform configuration)

Table II. Calculated Noise in a Six-Mile Idealized Joint-Use Exposure

	Untransposed	Transposition Section A	E	KA
Side circuit 1–2	2,200	25	0	15
Side circuit 3–4	950	50	80	15
Phantom circuit 1–4	5,800	1,900	0	0

800 to zero from one end of the exposure to the other. The telephone transposition arrangements within the six-mile exposure were taken as (1) untransposed, (2) the first six miles of an eight-mile *A* section (standard system[3]), (3) first six miles of an eight-mile *E* section[3] (exposed line system), and (4) a six-mile *KA* section[3] (*K*-8 phantomed system).

The magnitude of the noise for phantom circuit 1–4 in the case of the *A* section results largely from the fact that in this type of section the quarter points are not neutral points for phantom 1–4.

The degree of neutralization indicated by the tabulated values for the *E* and *KA* sections would not be expected to obtain in a practical joint-use exposure of this character, because of the effect of inevitable departures from absolute uniformity of exposure conditions and because of other differences from the idealized conditions assumed. It does appear, however, that in exposures likely to be encountered in practice the variation of the influence along the lighting circuit will be of less importance than the degree of uniformity of the exposure, the relative locations of the ends of the individual exposure zones, and the neutral points in the telephone transposition layout.

Summary of Conclusions

The following is a summary of the more significant facts brought out in the above discussion including an outline of measures which have been found effective in the noise-frequency co-ordination of series sodium lighting circuits and paralleling telephone lines:

1. The wave form of the current on a series lighting circuit supplying sodium lamps is approximately sinusoidal. The voltage wave, however, is distorted and somewhat irregular in character, roughly approximating a square wave (see figure 3). An analysis of the voltage wave indicates the presence of all the odd and many of the even harmonics of the fundamental supply frequency.

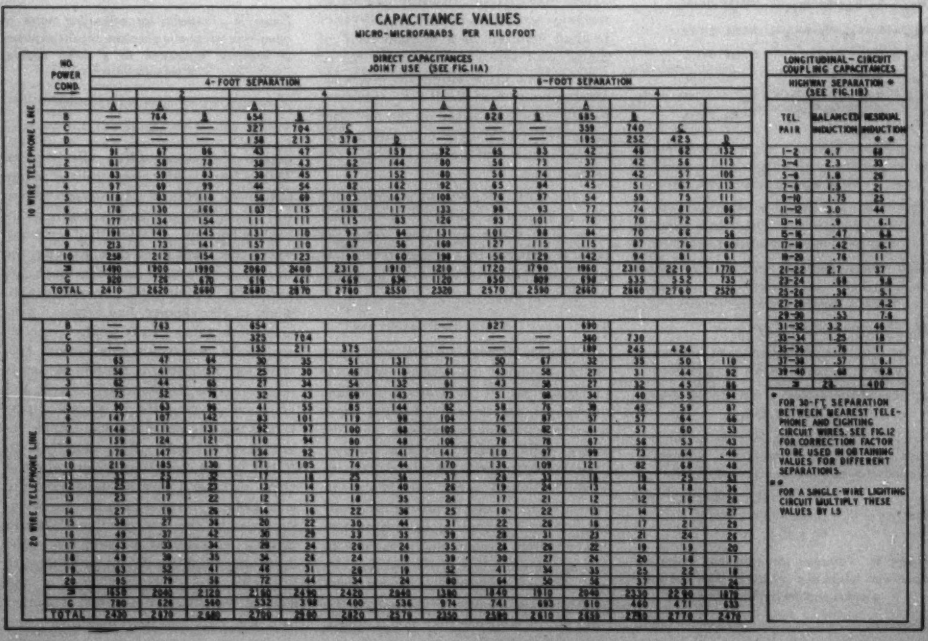
2. The wave-shape distortion on the lighting circuit is not transferred to the circuit supplying the constant-current transformer because of the relatively high leakage reactance of the latter.

3. Since only the voltage wave is distorted, electric induction in exposed telephone circuits is the only type of importance. Consequently, if either the lighting circuit or the paralleling telephone circuits are in metallic-sheathed cable, the shielding effect of the sheath will prevent appreciable noise induction.

4. The line-to-line $K_V T$ varies from a maximum at the constant-current transformer to a minimum at the far end of the circuit. The maximum $K_V T$ depends upon the number of lamps operating. However, the total $K_V T$ is not directly proportional to the number of lamps, indicating that the harmonic components from the individual lamps are not exactly equal or exactly in phase. The curve in figure 4 gives the total $K_V T$ observed on circuits supplying various numbers of lamps.

5. Since the influence varies from a maximum at the supply end to a minimum at the far end of the lighting circuit, the direction of feed may have an important effect on the magnitude of the induction. This will be most noticeable for nonuniform exposures—for example, where a section of joint use exists at one end of an exposure, the remainder of which is at highway separation. If in such a situation a choice were available as to the direction of feed, the location of the constant-current transformer at the end of the circuit remote from the joint-use exposure section would result in the lower magnitude of induction.

Figure 10. Capacitance values


CAPACITANCE VALUES
MICRO-MICROFARADS PER KILOFOOT
DIRECT CAPACITANCES JOINT USE (SEE FIG. 11A)
4-FOOT SEPARATION
6-FOOT SEPARATION
NO. POWER COND.
10 WIRE TELEPHONE LINE
20 WIRE TELEPHONE LINE
LONGITUDINAL-CIRCUIT COUPLING CAPACITANCES
HIGHWAY SEPARATION * (SEE FIG. 11B)
TEL. PAIR
BALANCED INDUCTION
RESIDUAL INDUCTION * *
1-2 4.7 68
3-4 2.3 35
5-6 1.8 26
7-8 1.3 21
9-10 1.75 25
11-12 3.0 44
13-14 .9 6.1
15-16 .47 5.8
17-18 .42 6.1
19-20 .76 11
21-22 2.7 37
23-24 .58 9.8
25-26 .36 5.1
27-28 .3 4.2
29-30 .53 7.8
31-32 3.2 44
33-34 1.25 18
35-36 .76 11
37-38 .57 8.1
39-40 .68 9.8
39 23. 480
* FOR 30-FT. SEPARATION BETWEEN NEAREST TELEPHONE AND LIGHTING CIRCUIT WIRES, SEE FIG. 12 FOR CORRECTION FACTOR TO BE USED IN OBTAINING VALUES FOR DIFFERENT SEPARATIONS.
* * FOR A SINGLE-WIRE LIGHTING CIRCUIT MULTIPLY THESE VALUES BY 1.5

6. The influence of a sodium lighting circuit (assumed ungrounded) is a minimum when the two wires of the circuit are kept close together (for example, adjacent pin positions) and when adjacent lamps are connected in opposite sides of the circuit. Figure 6 gives an indication of the relative effects of various lighting circuit arrangements.

7. With the lighting circuit arranged for minimum influence, that is, with no grounds, with the wires closely spaced, and with the lamps staggered, the induction in joint-use exposures is of the order of ten times that occurring at roadway (35-foot) separation.

8. For the lighting circuit arrangement just described (item 7), telephone circuit noise results chiefly from direct induction into the metallic circuit, since the longitudinal circuit induction is relatively small. Consequently, telephone circuit transpositions are effective in reducing this noise.

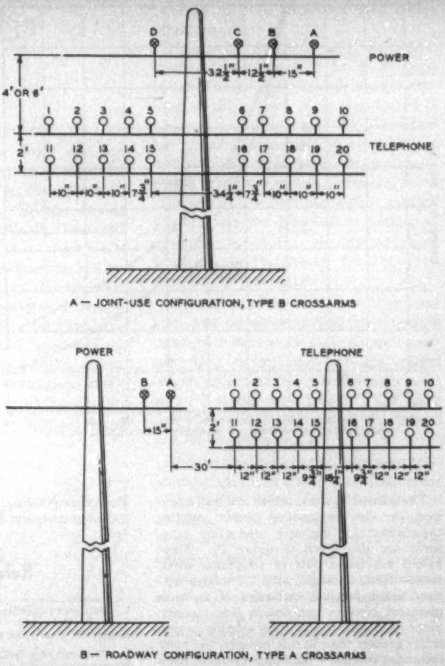
9. It appears that for reasonably uniform exposures at highway separation between open-wire telephone toll lines and a series lighting circuit, the noise induction will not be important if:

(*a*). The telephone lead is transposed according to the exposed line transposition system, or other systems having equal or greater frequency of transposition, and

(*b*). The lighting circuit is not grounded (or is grounded at a balanced point only), the two wires of the circuit occupy adjacent pin positions, and adjacent lamps are connected in opposite sides of the circuit.

10. In situations where only a small number of sodium-vapor lamps are used as, for example, at highway intersections, noise induction is negligible.

Figure 11. Line configuration



Appendix. Method of Estimating Noise

The usual methods of estimating noise[4] in transposed telephone circuits involve an empirical factor to take account of the effectiveness of the telephone circuit transpositions. The value of this factor depends upon the particular exposure and type of transposition arrangement. For reasonably uniform exposures with co-ordinated telephone-circuit transpositions, the factor can be obtained from accumulated experience data with a fair degree of accuracy. Where the telephone circuits are not co-ordinated or where the exposure conditions are quite irregular, the degree of effectiveness of telephone-circuit transpositions may vary over a wide range. The fact that exposures to series sodium lighting circuits may frequently involve both joint use and highway separation has made it necessary to use a method of estimating noise differing somewhat from those generally used.

The formulas employed for noise estimates in joint-use exposures are given in figure 8. The metallic-circuit noise is arrived at by first computing the total noise current to ground in each telephone wire caused by induction from the voltages to ground on each of the lighting-circuit wires. (It should be noted that where the lighting circuit is balanced to ground, the net noise current to ground in a given telephone wire is the *difference* between the induction from the two lighting wires.) This calculation makes use of the direct capacitances[5] between the lighting and telephone circuit conductors. The noise in a given metallic circuit is then obtained from the difference between the total longitudinal currents in the two sides of the circuit. This method is employed rather than a direct computation of noise metallic because of the difficulty of keeping track of the relative signs of the induction in various sections if the latter method is used.

As is indicated by the legend in figure 8, the formulas given are applied to a length of the exposure in which the configuration is uniform. The variation of the influence in such a section is taken into account by using the average value for the section. The usual type of exposure will need to be divided into a number of such sections, points of discontinuity being determined chiefly by the location of the telephone circuit transpositions and major changes in separation between the telephone circuits and the lighting circuit. In the case of toll circuits transposed as phantom groups, the computation of the total noise current in a given wire as, for example, wire 1 (N_1) may involve sections in which wire 1 is on each of the pin positions 1, 2, 3, and 4. The total noise current in wire 1 is then obtained by adding directly the components arising in the various sections.

Figure 9 shows the formulas employed for estimating noise in exposures at highway separation. These are generally similar to those in figure 8, except that the computation is carried out in terms of the balanced and residual components of the lighting circuit voltage instead of the voltage to ground of the individual wires. It will be noted that these formulas make use of "coupling capacitances" rather than the "direct capacitances" employed in the joint-use case.

Values of capacitances required in these formulas are given in figure 10 for the line configurations shown in figure 11. Direct capacitances are given in figure 10 for several joint-use exposure configurations. The "1 power conductor" data apply to a ground-return lighting circuit (or to a metallic circuit, the two sides of which are not on the same pole line) when the lighting circuit conductor is the only one on the power crossarm. If a single-wire lighting circuit were on the crossarm with three power conductors, the capacitance data for that wire would be selected from values for the "4 power conductor" case since the latter take into account the shielding effect of the other power conductors. These same considerations govern the selection of data for the case of a two-wire lighting circuit with both wires on the same pole line. While only a few of the possible number of combinations are covered, it will usually be adequate in a particular case to use the values for the condition most nearly representing the actual situation. In the practical case there are always present various irregularities in exposure conditions which it is not feasible to take into account, and hence noise estimates are necessarily approximate.

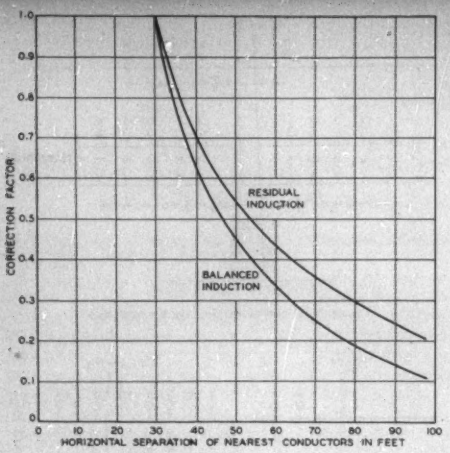


Figure 12. Correction factor for effect of separation for longitudinal - circuit coupling factors of figure 10

The available data, which are quite limited, on the longitudinal circuit coupling capacitance for highway separation exposures are also given in figure 10. These values are for a pair of telephone wires, rather than a single wire. Consequently they make possible estimates of noise in phantom circuits but not in side circuits. Since induction in phantom circuits is generally greater than in side circuits, the noise estimates will show the upper limits of noise to be expected. As an approximation, these capacitance values may be corrected for other values of separation between the lighting circuit and telephone circuits by means of the factors in figure 12. For a single-wire lighting circuit the residual induction values, increased by 50 per cent, should be used. If there are other conductors on the pole line in addition to the lighting circuit, the coupling capacitances will be reduced by the resulting shielding. This reduction may be of the order of 50 per cent.

Combination of Induction From Various Sections

In view of the apparent differences in phase of the harmonics arising in different lamps, it appears that the best method of combining the noise arising in the highway sections and the joint-use sections is to take the square root of the sum of the squares.

An opportunity to check these methods of estimating noise has been afforded in one field situation. In this case the open-wire telephone and toll circuits were transposed according to the *ABC* system and were exposed for 12 miles at highway separation and for 1.7 miles in joint use. The lighting circuit consisted of three sections, each approximately six miles in length. The two wires of the lighting circuit were located on adjacent pins (15-inch spacing) and a staggered arrangement of lamps was employed. The average contribution of the lighting circuits to the telephone circuit noise was estimated as 100 noise units for side circuits and 250 noise units for phantom circuits. The corresponding measured values were 150 noise units and 350 noise units.

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3. Engineering Reports, Joint Subcommittee on Development and Research, Edison Electric Institute and Bell Telephone System, volume 4 (1937). See report number 36, appendix I.

4. Engineering Reports, Joint Subcommittee on Development and Research, Edison Electric Institute and Bell Telephone System, volume 2 (1932), see report number 13, and volume 3 (1937), see reports numbers 16 and 17.

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Discussion

C. W. Frick (General Electric Company, Schenectady, N. Y.): Sodium lighting is a development which utilizes the high efficiency and other desirable characteristics of gaseous-discharge lamps. It does not displace incandescent lighting since each has its own field. In common with other devices in which conduction takes place through ionized gas, either the voltage or the current is distorted, in this case the voltage. The series arrangement does not lend itself to the application of devices for wave-shape improvement.

From the co-ordination standpoint there are three types of situations: first, where the number of lamps is small and the distorted voltage has negligible effect; second, where either the lighting circuit or the paralleling telephone circuits are in metallic-sheathed cable so that shielding practically eliminates the effect of distorted voltage; third, where fairly long parallels exist between open-wire circuits and the distorted voltage may cause noise induction under some conditions.

In the early installations the situations were either of the first or of the second type, and this still applies to a majority of the installations. A good example is the illumination of a traffic circle, an intersection, or a grade crossing. When the utility of this type of lighting for highways had been demonstrated situations of the third type began to appear. It is worthy of note that cooperative studies were undertaken before any of these situations actually developed. The co-ordinative measures described in the paper resulted from these studies. If installations such as the one 16 miles long referred to by the authors had been planned without any thought of co-ordination, the pin position nearest the road might have been chosen for the lighting circuit and all the lamps connected in that wire. The other wire might then have been put in a similar position on the opposite side of the crossarm. The studies showed, however, that such an arrangement would not have given the best results. Actually, arrangements have been chosen which were recommended for minimizing the inductive effects. Thus the lighting circuits have been planned with wires on adjacent pins and the lamps alternated between wires, as recommended in the paper.

When an installation is contemplated where conditions of the third type exist, the data in the paper should be carefully considered from the point of view of both the lighting circuit and the telephone circuit. For roadway separation the problem is practically solved when the recommendations are followed. Up to the present time there has been only a limited amount of experience with these open-wire circuits at joint-use separation.

At the present time there are over 6,000 sodium luminaires in service and we know of no reports of telephone interference from this cause.

P. W. Blye: As mentioned by Mr. Frick in his discussion, it is important, where a parallel is to be created between a series sodium lighting circuit and an open-wire telephone line, that the inductive co-ordination aspects be considered in planning the arrangement of the lighting circuit. A co-operative study of the situation by the power and telephone companies involved, including an estimate of the noise induction, will indicate whether or not special co-ordinative measures will be necessary either in the lighting circuit design or in the telephone line. In cases where special measures are necessary their installation in advance of the energization of the lighting circuit will generally be found not only most economical but also most desirable from the standpoint of avoiding inconvenience to either utility. The present paper has been arranged to provide the technical data required in the co-operative consideration of such problems.

Electromagnetic Horn Design

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Synopsis: The principles of designing electromagnetic horn "antennas" to obtain beams of specified angular spread, smoothness of contour and power gain are disclosed. Quantitative curves are given from which the design of sectoral and pyramidal horns may be readily made.

THIS PAPER deals with the transmission and reception of ultrahigh-frequency electromagnetic waves by flared horns of metal. Several earlier papers (see bibliography) have described the operation and some of the applications of these new "antennas" and have reported fundamental research of both experimental and theoretical nature. In this paper, some of the more important principles of design will be discussed. Numerical data based on theoretical considerations will be presented that permit the specification of horn dimensions for given radiation performance.

General Considerations

The electromagnetic horn comprises a formed sheet of conducting material flared from a "throat" or small end to a "mouth" or large end. In applications to transmitting, electromagnetic energy delivered to the throat propagates through the interior of the horn to the mouth as "horn waves." At the mouth, substantially all of this energy is radiated as free-space or ordinary radio waves. In applications to receiving, a similar but reverse process occurs. It may be shown by the general theorem of reciprocity for electromagnetic systems, that a given horn will have characteristics as a receiver similar to those that it has as a transmitter, hence the material to follow applies to both applications.

Although a wide variety of shapes is possible, a shape having a rectangular cross section perpendicular to the central axis of the horn is preferable, because it is capable of producing a linearly polarized wave. The rectangular shape also permits an independent control of the width of the radiated beam in the horizontal and vertical planes. Horns having straight sides in the longitudinal cross section have been most used, because of the economy and ease of construction and because thorough analysis of this structure has been made. Pyramidal and the sectoral horns, having both sides flared and having two opposite sides flared and the other two opposite sides parallel, respectively, are the most important examples. The analysis of this paper applies directly to sectoral horns and indirectly to those of pyramidal shape.

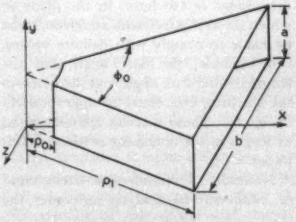

Figure 1. Sketch of sectoral horn showing dimensions

The material from which the horn is made may be any of the highly conducting metals. Galvanized iron sheeting and thin electrolytic copper foil cemented to plywood have both proved satisfactory. Screen or other semiopen construction may also be employed. Dielectric supports and insulators are not required in any region of intense field, consequently dielectric losses are low. For protection from weather, however, the mouth may be tightly covered with a dielectric material, such as silk, fabric, or plywood.

Two general methods of exciting the horn are available; namely (1) hollow-pipe feed, and (2) direct excitation. In the first case a hollow-pipe transmission line is connected to the throat, and in the second case an exciting rod or other radiating means, such as a vacuum tube, is disposed directly in the throat. The first method is mainly useful for wave lengths less than about 20 centimeters, but the second method is applicable to longer waves. Experiment has shown that substantially the same radiation patterns may be produced with either arrangement.

Figure 12 shows a large pyramidal electromagnetic horn that was designed in accordance with the principles outlined in this paper. It is constructed of plywood and copper foil. It is designed for optimum sharpness of beam in the vertical plane when operated at a wave length of 50 centimeters. This horn was constructed in connection with a research program on the instrument landing of airplanes conducted at Massachusetts Institute of Technology for the Civil Aeronautics Authority.

The sketch of figure 1 shows a sectoral horn and serves to define the following quantities: flare angle ϕ_0, horizontal aperture b/λ, vertical aperture a/λ, radial length ρ_1/λ, and the cut-off length ρ_0/λ, where λ is the wave length. The same unit of length is used for all dimensions and for the wave length.

Propagation within the horn may take place by means of any of several different types of horn waves, or by a combination of them. Which of the types is present depends on the configuration of the exciting system at the throat or of the waves delivered there by a hollow-pipe transmission line, and also on the flare angle ϕ_0 and the cut-off length ρ_0/λ. Expressions for the field configurations and transmission properties of these waves may be obtained by solving Maxwell's equations in cylindrical co-ordinates and satisfying the boundary conditions on the surfaces of the horn.[6] In general, two distinct groups of waves result; namely, *E* waves, having no radial component of magnetic intensity, and *H* waves, having no radial component of electric intensity.* For most applications of the horn, the *H* waves are employed, particularly the two waves of lowest order, $H_{0,1}$ and $H_{1,0}$. The reason for this choice is found in the fact that the configuration of the field of these waves inside the horn is such as to produce single-lobe beams of linear polarization in the radiated wave.

Sketches of the field configurations of the $H_{0,1}$ and the $H_{1,0}$ waves are reproduced in figure 2. The electric intensity in the $H_{0,1}$ wave is everywhere parallel to the *y* axis, is uniform in intensity in this direction but has a half-sinusoid distribution in intensity along an arc between the two flared sides. The magnetic lines lie in planes perpendicular to the *y* axis. This wave may be excited by a current-carrying rod in the throat disposed par-

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6. For all numbered references, see list at end of paper.

* Two subscripts, *m* and *n*, are required to define a particular wave. These subscripts give the number of half sinusoids in the field distribution between the two parallel sides and between the two flared sides, respectively.

allel to the y axis, or by feeding an $H_{0,1}$ wave into the throat from a rectangular hollow pipe. In the $H_{1,0}$ wave, the electric lines of force lie along arcs between the two flared sides; they have a uniform distribution along the arc, but a half-sinusoid distribution in the y direction. The magnetic lines lie in planes passing through the y axis. This second type of wave may be excited by a current-carrying rod disposed centrally in the throat parallel to the x, z plane and along an arc about the vertex, or by feeding an $H_{1,0}$ wave into the throat from a rectangular hollow pipe. Both waves have constant phase on cylindrical surfaces about the y axis.

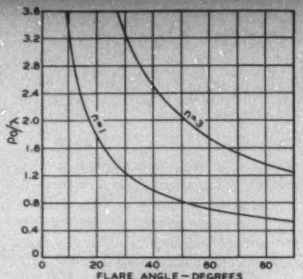

Figure 3. Throat design curves

Optimum cut-off length ρ_0/λ for the $H_{0,1}$ wave ($n = 1$) and the radial extent of the high attenuation region for the $H_{0,3}$ wave ($n = 3$)

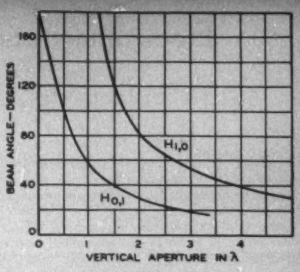

Figure 4. Beam angles in the vertical plane for $H_{0,1}$ and $H_{1,0}$ waves

Design Considerations

In the design of electromagnetic horn radiators, two aspects of the horn are of fundamental importance. The first of these has to do with the excitation within the horn of the desired type of wave to the exclusion of waves of other types. In addition to the provision of an appropriate disposition of the exciting rod or rods, it is also necessary to make the size of the throat and the radial length of the horn of such values that the desired wave only will be produced for radiation at the mouth. The determination of these values will be discussed in the section entitled "Throat Design." The second important aspect of design concerns the radiation into space of a beam that meets the given requirements as to smoothness, sharpness, and concentration of the radiant energy in one direction. Two of the dimensions of the horn, in the plane in which these requirements are given, must be made to comply with definite values. For example, the flare angle and the length, or the flare angle and the horizontal aperture, etc., must be appropriately designed. These matters are considered at length in the remaining sections of this paper.

Naturally, a considerable background of mathematical analysis antecedes the quantitative curves and the discussions of this paper. This analysis, which is in part published elsewhere,[3,4] has been omitted from this paper in order to emphasize the design of actual horns for specific applications. Experimental measurements have been likewise omitted, although on hand in abundance. Some experimental results have already been published.[3,5]

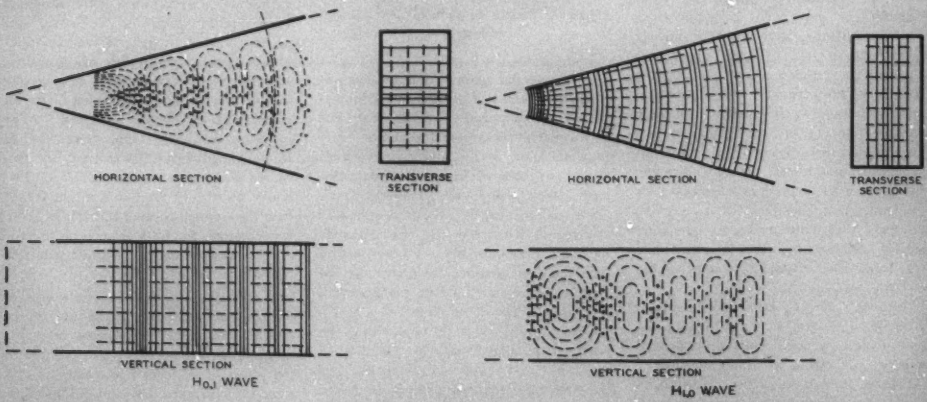

Figure 2. Field configurations for $H_{0,1}$ and $H_{1,0}$ waves in a horn

Solid lines represent electric lines of force and dotted lines represent magnetic lines of force

Throat Design

In the vicinity of the exciting rod, a plurality of the different types of horn waves will be generated. In many applications a single wave, say $H_{0,1}$, should obtain near the mouth, as the radiation pattern will be distorted by the presence of other waves. A single wave near the mouth can be realized by appropriate design of the throat. The magnitude of the attentuation of each wave is relatively large near the apex but is progressively smaller at greater radial distances. The radial distance to which the region of relatively high attenuation extends is greater for waves of higher order than for waves of lower order. Consequently, in a horn of given flare angle, a particular value for the cut-off length ρ_0 can be given that permits the $H_{0,1}$ wave to reach the mouth substantially unattenuated but which affords almost complete at-

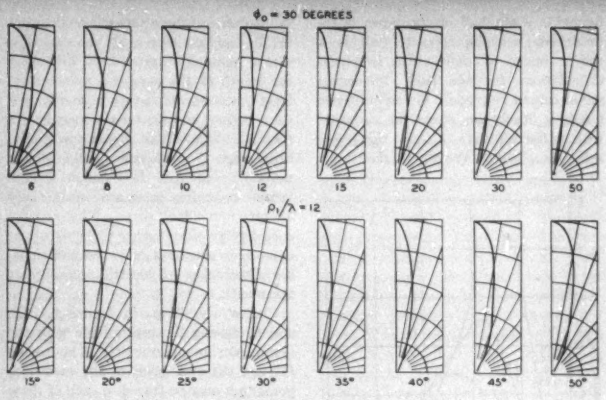

Figure 5. Two typical series of horizontal radiation patterns for the $H_{0,1}$ wave

Upper series for constant flare angle of 30 degrees and variable radial length. Lower series for constant radial length of 12 and variable flare angle

tenuation or filtration of higher order waves. This value of ρ_0 will be referred to as the "optimum cut-off length." Horns for the production of single-lobe smooth beams should have their cut-off lengths not too different from this optimum value. Figure 3 shows graphically the relation between the optimum cut-off length and the flare angle for the $H_{0,1}$ wave. For comparison, the radial extent of the high-attenuation region for the $H_{0,3}$ wave is given by the curve $n = 3$. The vertical dimension a affects neither the transmission characteristics of the $H_{0,1}$ waves nor the filtration of higher order waves except when $a > > \lambda$.

When radiation by means of the $H_{1,0}$ wave is desired, the $H_{3,0}$, $H_{5,0}$, . . . waves must be eliminated or filtered, which may be achieved by adjusting the dimension a. The $H_{1,0}$ wave is able to travel freely in the radial direction when $a > \pi/2$, but the $H_{2,0}$ wave requires $a > (3\lambda)/2$ for free transmission, etc. Therefore, to eliminate the higher order waves, the dimension a must be slightly greater than one-half wave length but less than three-halves wave lengths. The $H_{2,0}$ and $H_{4,0}$ waves can be prevented by constructing the exciting system with even symmetry about the plane $y = a/2$ equidistant from the two parallel sides of the horn.

Special cases may arise wherein several wave-types may be used simultaneously. It will be assumed in the remainder of this paper, however, that the construction of throat and exciting means is such that either an $H_{0,1}$ or an $H_{1,0}$ wave alone exists in the horn.

Radiation Characteristics

When the horn waves reach the mouth, they become free from the guiding surfaces and spread out as radiant energy. The relative amplitude of the electric field intensity on a sphere of fixed radius large compared to wave length and aperture comprises the space radiation pattern. The radiation pattern along the intersection of this sphere and the x, y plane will be referred to as the vertical pattern and that along the x, z plane as the horizontal pattern. The discussions of this paper are confined to these two plane radiation characteristics.

In evaluating the effectiveness of a given horn to produce a directed beam of radiation, recourse to the following knowledge is useful: (1) the detailed shape of the radiation pattern, such as the presence and relative amplitudes of secondary lobes; (2) the angular width of the beam, or the "beam angle," defined here as twice the angle measured from the forward axis of the radiation pattern to the nearest radial line in this pattern along which the magnitude of the electric field intensity is ten per cent of its value on this axis; and (3) the relative power gain, defined as the ratio of the power radiated from a dipole to that radiated from the horn to produce, in each case, the same magnitude of electric field intensity at a fixed remote point on the x axis.

The radiation patterns were computed by means of Huygens' principle from the distribution of the Hertzian vector at the mouth.[2] This distribution was assumed to be the same as that which would exist at the plane of the mouth were the horn infinitely long: experiments have justified this assumption for most practical cases. The radiation patterns were plotted both in rectangular and in polar co-ordinates, and the beam angle was measured from the rectangular plots. The power radiated by the horn was obtained by integrating the Poynting vector over the mouth with the field at the mouth adjusted to give unity power density at a fixed distance r on the x axis from the origin. The power radiated by the dipole for the same effect is $(8\pi r^2)/3$. Al-

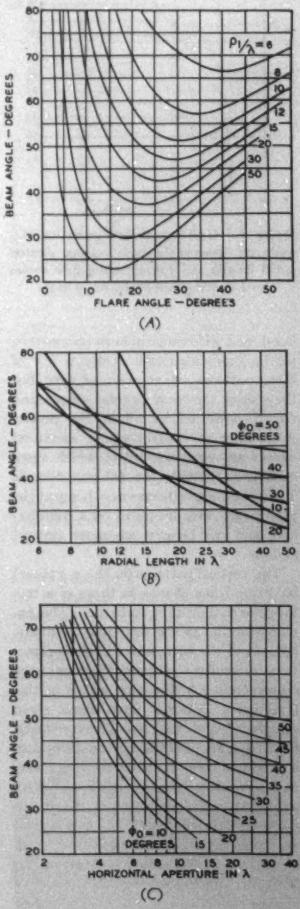

Figure 6. Beam angle in horizontal pattern for $H_{0,1}$ wave versus (A) flare angle, (B) radial length, and (C) horizontal aperture

though the power gain obtained in this way does not include copper losses in either horn or dipole, it is believed sufficiently accurate for most purposes.[6]

In the course of this research over a hundred radiation patterns were calculated for a wide range of horn parameters, plotted, and analyzed. Only a few of these patterns are reproduced here, but they show the same general shapes and trends possessed by all of the curves. A number of experimentally measured curves are on hand,[6] all of which agree satisfactorily with the calculated ones. Thus, the composite curves of beam angle, power gain, etc. are based on a considerable and, we believe, adequate amount of data.

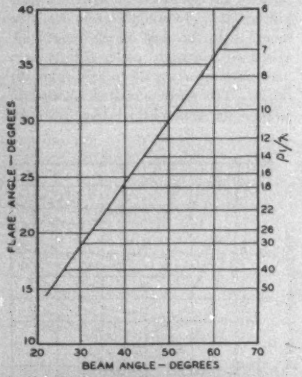

Figure 7. Optimum design curve for $H_{0,1}$ wave on beam-angle basis, giving shortest radial lengths and corresponding flare angles for a specified horizontal beam angle

The vertical patterns (in the x, y plane) have the same shapes as those of a rectangular hollow-pipe radiator. The explanation lies in the fact that the distributions of the horn waves in the y direction are similar to the distributions of the corresponding hollow-pipe waves in this direction. Patterns have been given elsewhere[3] and will not be reproduced here. The shape of the patterns comprises a principal lobe centered on the x axis and secondary lobes of relatively small amplitude. The sharpness of the principal lobe depends mainly on the vertical aperture a/λ. Figure 4 shows curves of beam angle versus vertical aperture for both $H_{0,1}$ and $H_{1,0}$ waves.

$H_{0,1}$ Wave

Two typical series of horizontal patterns for the $H_{0,1}$ waves are shown in figure 5. Only half of the beam is reproduced, but the opposite half is a mirror image of that which is given. Calculations for the back 180-degree sector cannot be made. The upper series for $\phi_0 = 30$ degrees shows the variation with radial length ρ_1/λ, and the lower series for ρ_1/λ shows the effect of flare angle ϕ_0. A glance at these patterns reveals that (1) for constant flare angle the sharpness of the beam is improved by increasing the length of the horn, up to a certain length, beyond which very little improvement occurs, and (2) for constant length there is a value of flare angle for which the beam angle is maximum. Although the radiation patterns show slight irregularities, secondary lobes are substantially absent from all of them. This fact, of considerable significance to some applications, is attributable to the half-sinusoid distribution of electric intensity at the mouth.

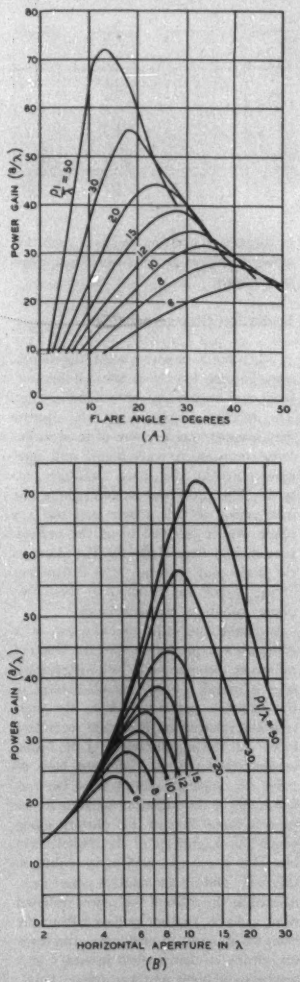

Figure 8. Power gain for $H_{0,1}$ wave versus (A) flare angle and (B) horizontal aperture

The values of power gain as read from the ordinate scale must be multiplied by the vertical aperture a/λ of the horn

Curves are shown in figures 6*A*, *B*, and *C* relating the beam angle with the several design parameters. The trends (1) and (2) mentioned in the preceding paragraph may be traced in each of these curves. In particular, each curve in *A* has a minimum, and a line connecting these minima would be approximately a straight line through the origin. Such a straight line defines the shortest horns that may be employed to produce a beam of specified angle. A corresponding envelope line could be drawn in *B*.

Optimum conditions may be expressed numerically by plotting associated values of optimum flare angle and length versus the beam angle, as has been done in figure 7. This important design curve permits the ready specification of optimum horn dimensions for a beam of given angle.

Curves showing the variation of power gain with flare angle for a number of constant radial lengths are reproduced in figure 8*A*. Here, too, one finds that for a horn of any given length there is an optimum flare angle. In this case, it provides maximum power gain. The

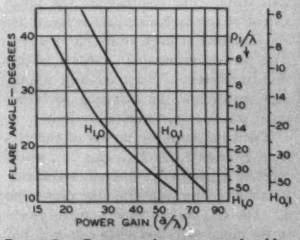

Figure 9. Optimum design curve for $H_{0,1}$ wave and $H_{1,0}$ wave on a power-gain basis, giving shortest radial lengths and corresponding flare angles for a specified power gain

The values of the power gain as read from the abscissa scale must be multiplied by the vertical aperture a/λ of the horn

values of the maxima occur at smaller flare angles for increasing lengths of horn. The magnitude of the maximum power gain increases with increasing length. Figure 8*B* shows the variation of power gain with horizontal aperture. If the abscissas are multiplied by a/λ, this curve will show the variation of power gain with the transverse area of the mouth. Clearly, the gain is not a simple function of the mouth area.

The peaks of the curves in figure 8 provide optimum design conditions on a power gain basis. These optimum values of flare angle and length that provide maximum power gain are plotted in figure 9. This curve, as well as the accompanying one for the $H_{1,0}$ wave, allows the specification of optimum horn dimensions for a given power gain and supplements the curve of figure 7.

The absolute magnitude of the power gain is plotted for a vertical aperture a/λ = unity, but one should note that the power gain is directly proportional to the vertical aperture. Consequently, the values of power gain given in the curves are to be multiplied by the value of a/λ of the horn in question. Clearly, quite enormous power gains may be obtained. For example, for a horn of length ρ_1/λ = 50 having an optimum flare angle of 14° and a vertical aperture of a/λ of 10, the power gain is 720. A horn of these dimensions is entirely feasible and of moderate size at wave lengths of, say, ten centimeters. The power gain of the horn shown in the accompanying photograph is calculated to be 50.

$H_{1,0}$ Wave

Two representative series of horizontal radiation patterns (in the x, z plane) are shown in figure 10. The upper series is for horns of a constant flare angle of 35 degrees and the lower series for horns of a constant radial length of 15. The same general trends are found here that were noticed in figure 5 for the $H_{0,1}$ wave. However, the order of magnitude of the secondary peaks in the patterns is considerably greater with $H_{1,0}$ waves. For horns of equal length, increasing the flare angle from a small value at first will sharpen the principal part of the beam. It also increases the magnitude of the secondary peaks. For sufficiently large flare angles, these secondary peaks become larger than the principal beam. As a consequence, the beam becomes broader as the flare angle is increased. For horns of constant flare angle the tendency is also observed for the beam to broaden as the length of the horn is increased. However, for sufficiently great lengths, the width of the beam is substantially equal in magnitude to the flare angle.

The explanation of the exaggerated secondary peaks in the pattern of the $H_{1,0}$ wave lies in the uniform distribution of the field across the mouth in the horizontal direction and the abrupt discontinuity at the edges. The irregular shape of the horizontal patterns makes it impractical to define a beam angle and reference must be had to the actual radiation patterns.

Power gains for the $H_{1,0}$ wave are given by the curves of figure 11*A* and figure 11*B*. The general behavior of these curves is similar to those of the curves for the $H_{0,1}$ wave. The small oscillation of power gain at large flare angles is associated with the shift of the energy from principal lobe to secondary lobe, as described above. The power gain is a

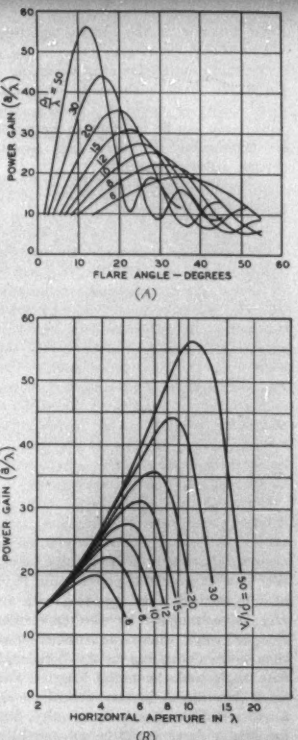

Figure 11. Power gain for $H_{1,0}$ wave versus (A) flare angle and (B) horizontal aperture

The values of power gain as read from the ordinate scale must be multiplied by the vertical aperture a/λ of the horn

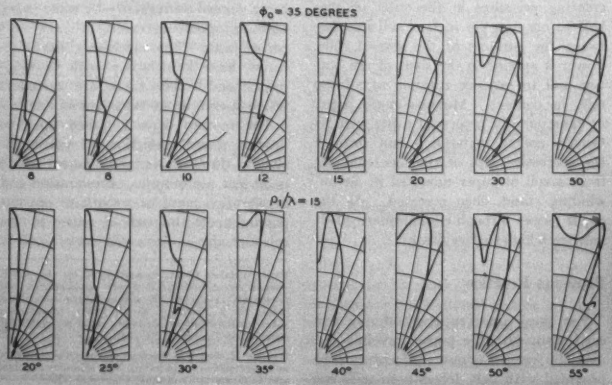

Figure 10. Two typical series of horizontal radiation patterns for the $H_{1,0}$ wave

Upper series for constant flare angle of 35 degrees and variable radial length. Lower series for constant radial length of 15 and variable flare angle

Figure 12

linear function of the vertical aperture a/λ for the $H_{1,0}$ wave also.

Optimum design for $H_{1,0}$ waves on a power gain basis is shown by the indicated curve of figure 9. Clearly, the power gain can be indefinitely increased by lengthening the horn and appropriately reducing the flare.

Concluding Remarks

Comparing the operation of the sectoral horn with the $H_{0,1}$ and the $H_{1,0}$ waves we arrive at the following conclusions. The $H_{0,1}$ wave gives a clean-cut beam comprising a principal lobe without appreciable secondary lobes, and the beam angle can be well controlled. The $H_{1,0}$ wave also gives a clean-cut beam for flare angles less than those required for maximum power gain, but an irregular beam for greater angles. On a power gain basis, there appears to be substantially no difference between the two waves.

Horns of pyramidal shape; that is, flaring in both transverse directions, may be designed on an approximate basis by means of the data presented in this paper. We may express the power gain $P_{0,1}'$ of a pyramidal horn operating with an $H_{1,0}$ wave roughly by the expression $P = kP_{0,1}\ a/\lambda$, where k is a numeric less than unity depending on the horizontal flare angle and the radial length. For small flare angles in the vertical plane, k will not differ greatly from unity, but for greater flares it will be substantially less than unity. When using an $H_{0,1}$ type of wave in a pyramidal horn, the vertical flare angle should be kept small if a clean-cut vertical radiation pattern is desired.

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Electric Drives for Supercalenders in Paper Mills

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A TYPICAL electric drive for a modern 84-inch supercalender and winder consists of a 200-horsepower adjustable-speed driving motor, two 20-horsepower motors for winder drums, a 150-kw variable-voltage motor generator set with 30-kw winder generator and exciter, full magnetic control with large motor-operated rheostat, and an operator's panel. The drive will provide a threading speed of 50 feet per minute and a wide range of many productive calendering speeds to a maximum which may be 2,000 feet per minute. With auxiliary equipment on the winder slitters, and pressure-applying arrangement, the operator has full control of the calender speed, starting and stopping, roll pressures, and winder tensions at a central point.

In the last two decades progress in the development of electric drives for paper-mill supercalenders has resulted in their adaptation to many existing calenders as well as in their selection for new calender installations.

The Supercalender

The supercalender is a machine consisting of a vertical stack of smooth-surfaced rolls, usually alternately steel and composition fiber, either cotton or paper, with means for applying and regulating pressure on the top roll, thereby creating pressures in the order of one-half to one ton per inch of roll face between the surfaces of the several rolls. Power is applied to the shaft of the bottom roll to produce rotation of all the rolls in contact. Machine-made paper or subsequently processed paper such as heavily coated material is run through the successive nips of the supercalender from a roll of paper mounted in an unwinding stand, then rewound. As the paper passes through the calender rolls it receives a high surface finish.

Previous Practice

For many years supercalendering was carried on with the paper traveling not over 500 feet per minute. Machines were provided with belt drives from mill line shafts, and mechanical clutches. Threading of the web of paper through the rolls to get each roll started was accomplished by slipping the clutch, or in some cases by the use of back gearing. Each machine was limited in respect to its productive speed. Higher productive speeds were seen to be desirable to increase calendering operations with such grades of paper as could be properly finished with faster operation, but some grades of paper could not be handled and properly finished at increased speeds. This situation called for means for selecting calendering speeds to suit a variety of conditions. At this time it was recognized that with some grades of paper, slower productive speeds might result in less loss of product and less interruption due to paper tearing and the web breaking, and particularly that means were needed for providing a stable, very slow, calender speed for threading, because considerable material and time were being lost because of paper breaks occurring in the course of getting paper started through the calender.

Essential Requirements

As adjustable-speed drives were applied to supercalenders to make available higher speeds, improvements took place in the design of bearings and methods of lubrication, and in calender roll properties. By 1926, supercalendering was being carried on regularly by some paper mills at speeds in excess of 1,000 feet per minute. The machinery manufacturers have kept apace with developments and today there are calenders which operate at 2,000 feet per minute.

The modern drive is called upon to provide a wide selection of speeds, including the threading requirement which is 50 feet per minute. Acceleration and deceleration must be smooth to prevent pulling apart the web of paper in the calender nips and to avoid uneven pull in

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the span of paper from the unwinding roll to the calender, and in the span from the calender to the roll winding-up. Quick stopping is essential in order to keep the passage of wrinkled paper between the rolls to a minimum when a paper break does occur because the calender's composition rolls are made of compressed cotton or paper. The smooth surfaces of these rolls become marred ultimately from wrinkled paper in the machine and time taken for regrinding rolls cuts into the productivity of the calenders.

Electric Drive System

In the course of securing adjustable speed by electric drives and working up from the previous 500 feet per minute maximum productive speed, there have been several methods employed. Where direct current was available or provided the shunt-design d-c motors were used and productive speeds obtained by field weakening the motor, with constant armature voltage. Threading speed was obtained by reduced armature voltage using external resistances in series with and shunted across the armature. Variations of this system to serve several drives in the same calendering department involved the use of two or more voltages in the power circuit, for example both 250 and 125 volts for the motor armature with further range of speed adjustment by field weakening available with the armature connected to either voltage, and 35 volts as a source of armature voltage for threading operation eliminating external armature resistance.

Drives were developed to operate on a-c circuits, these being of the wound-rotor induction-motor type. The selections of speeds for productive operation were made with adjustable secondary or rotor resistance. Threading speed was provided, either by use of an auxiliary squirrel-cage induction motor, driving through a suitable reduction and overrunning gear, or by a separate reduced-frequency and alternating-voltage circuit for the wound-rotor motor.

The variable-voltage, or adjustable direct-voltage system was introduced for paper mills not having direct current available, but where the characteristics of the d-c motor were wanted. This involved a motor generator set operating on the mill a-c circuit, with rheostatic field control of the generator to provide adjustable-output direct voltage for the armature circuit of a shunt-design d-c motor used for driving the supercalender. A separate exciter, usually coupled into the motor generator set, furnished a source of constant voltage for the shunt field and control circuits. Threading speed was provided by impressing a low voltage on the motor armature, smooth acceleration and deceleration by adjusting the voltage gradually and smoothly over a wide range between minimum and maximum available armature voltage.

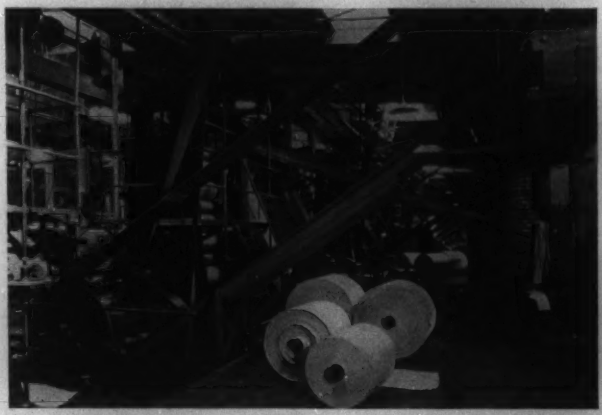

Figure 1. Belt drive for supercalender, commonly used before development of modern electric drives

The recent supercalenders installed for operation over wide speed ranges to maximum speed of 1,200 to 2,000 feet per minute are equipped with variable-voltage drives. The use of a low armature voltage to the motor, or of an auxiliary threading motor with suitable reduction gears and an overrunning clutch, are alternate methods of obtaining the threading speed. In many cases, speed adjustment by motor field weakening supplements the range of speed change available by voltage control giving the drive the characteristics of the shunt d-c motor with constant armature voltage over the normal productive range of calendering speeds.

Load Characteristics

The power requirement of a supercalender is made up of three principal components, (*a*) the work done in overcoming the mechanical frictional losses in the bearings and gearing, (*b*) the work done in the constantly changing deformation taking place in the calender rolls in rotation under contact pressure, and (*c*) the work done on the paper being calendered.

From a large number of observations studied, it appears that for a given set of conditions each component has a constant torque characteristic wherein the horsepower requirement is directly proportional to the linear speed. This pertains over the productive speed range of the calender within the normal capacity of the machine in respect to the pressures applied to the rolls, roll condition, bearing design and lubrication. Tests have shown repeatedly that when the normal conditions for which a machine is designed are exceeded, the load requirement at increased speeds rises abruptly. Recognizing the constant torque characteristic for a given set of conditions, the maximum torque requirement of a supercalender is in some cases that required to drive the calender with heavy roll pressure for a hard finish on a relatively heavy paper normally calendered at some intermediate speed rather than the torque required for calendering the grades of paper which are run through at the maximum linear speed.

The following load information was reported on a modern nine-roll calender, 75 inches wide, equipped with antifriction bearings, the loads expressed in terms of calender roll face and linear speeds:

1. Running without paper and with no pressure applied in addition to weight of rolls themselves.....0.031 horsepower per inch face per 100 feet per minute

2. Running without paper but with pressure applied of 1,780 pounds per inch width in addition to weight of rolls...0.091 horsepower per inch face per 100 feet per minute

3. Running with paper 65½ inches wide, basis weight 35 pounds per ream of 500 sheets 24 by 36 inches, with pressure applied of 1,780 pounds per inch width . . 0.132 horsepower per inch face per 100 feet per minute

This is typical in respect to the division of the total load requirement of a supercalender.

Supercalenders made up of alternate steel and composition cotton rolls and used for calendering heavily coated paper require more power than calenders with steel and composition paper rolls used for putting a higher finish on paper as it comes from a paper machine without any further processing, as indicated by a comparison of the following load factors which are averages of observations taken over a long period on several antifriction-bearing calenders:

Cotton and steel rolls—medium weight papers, normal pressures . . . . . 0.140 horsepower per inch face per 100 feet per minute

Paper and steel rolls—medium weight papers, normal pressures . . . . . 0.10 horsepower per inch face per 100 feet per minute

Supercalender Winders

Many supercalenders are equipped with the conventional type of two-arm rotating reels for mounting the unwinding rolls and the cores on which the paper is rewound. A friction brake on the shaft of the unwinding roll produces tension in the web of paper as it enters the calender, and the shaft of the rewinding roll is driven by a belt from a pulley on the shaft of the bottom roll of the calender. As some paper-mill managements found it possible to improve calendering operations with improved equipment and to supply their customers with the paper rolls as they were rewound at the calender without further rewinding to remove imperfect paper, other types of winders were brought into tandem operation with the calenders. These provide for trimming the web of paper and slitting it to desired widths in rewinding.

Surface-Type Winders

There are various designs such as the four-drum winder having an individual motor driving each drum, the two-drum and single-drum winders which wind by the surface principle, the motors for which are controlled automatically to keep in step with the main motor driving the calender and to produce desired tension for handling the sheet properly and securing good finished rolls. Many of these winders are driven by d-c motors with adjustable-voltage control for the overall linear speed range with supplementary or vernier speed control actuated by a counterweighted roll or dancer roll, over which the sheet passes as it travels from the calender to the winder. One electrical manufacturer has supplied a winder system making use of wound-rotor induction transmitter driven by the calender motor and the wound-rotor induction receiver mechanically connected to drive the winder. The primary or stator circuits are commonly excited from the mill a-c circuit and a wound-rotor induction differential is introduced in the rotor circuit. By properly controlling the angular position and rotation of the differential unit, the receiver gains on the transmitter from which it is principally controlled sufficiently to develop the tension desired for proper winding of the roll.

Figure 2. Electric drive for supercalender and two-drum winder having individual motor driving each winder drum

Operator's panels at left mount starting and stopping push-button stations, switches for individual slitter motors, instruments indicating calender speed and motor load, and controls for adjusting roll pressure and winder tension

Center-Driven Winders

Some supercalenders are equipped with motor-driven winders of the center or core-shaft drive type. With these the motor driving the winding roll must continually fall off in speed as the roll of paper increases in diameter while no change is taking place in the linear speed of the calender, and simultaneously uniform tension of the sheet must be maintained to produce a good roll. The prevailing practice of using three-inch and four-inch diameter cores for paper rolls for the printing industry has been a limitation preventing the adaptation of tension-controlled motor drives using a field-control d-c motor and automatic regulator working in the field of the motor to maintain constant armature current because the full rolls are 32 inches to 40 inches in diameter. The same limitation has hindered the application of corresponding equipment on unwinding roll for controlling tension automatically

Figure 3. Modern supercalender with variable-voltage d-c driving motor

Magazine reel holds unwinding roll, additional rolls to follow in process, and the electric drive for shaft of core on which paper is rewound

in the sheet entering the calender. Field regulation over a motor or generator speed change of ten to one would be required and this is recognized as a wider range than is available in commercial machines today. The motors which have been applied to shaft or center-driven winders operating in tandem with supercalenders for winding rolls where the ratio of full roll diameter to core diameter is ten to one are of the d-c series design operating in conjunction with specially compounded generators. The regulation of the motor field strength and armature voltage is accomplished inherently in the system by the changing armature current which increases as the roll increases in diameter.

Conclusion

Supercalenders and their winders are outstanding examples of process machines for which motors are called upon to provide unusual flexibility. In addition to transmitting power, the electrical equipment is a production tool vital to the performance of the machine.

Discussion

D. R. Shoults (General Electric Company, Schenectady, N. Y.): We are indebted to Mr. Smith for an interesting résumé of past and present practices in driving supercalenders and their auxiliary equipment.

There have been a number of types of drives used for supercalenders, most of which were reasonably successful when operating at speeds of 500 feet per minute or less, but without question the recent emphasis on high calendering speeds, with a consequent emphasis on ease of acceleration and retardation with readily adjustable operating speeds, has required that the drive used be unusually flexible. The natural trend in such a situation, as Mr. Smith has pointed out, is toward the use of the adjustable-generator-voltage-controlled drives. Such drives lend themselves very well to coordinated winder drives or electrical braking systems for unwinding stands.

Another factor which has become of increasing importance as speeds are increased is that of nip pressure between the rolls. In order to obtain equivalent finish on the paper at high operating speeds, the operators have found it necessary to increase the nip pressure considerably above the values common a few years ago. A bottom roll nip pressure of at least three times the pressure resulting from the weight of the rolls themselves is today common practice. Such high pressures give increased roll deformation and naturally influence materially the power requirements of the drive.

Mr. Smith cites a 75-inch-wide supercalender with nine rolls which has a power constant of 0.132 horsepower per inch face per 100 feet per minute. The pressure is 1,700 pounds per inch of width which is assumed to be at the bottom nip. I would like to know whether this calender was equipped with paper or cotton composition rolls. If these rolls are of paper, I believe that that particular requirement is typical, but if they are of cotton, it seems that this value is somewhat low. Mr. Smith subsequently states that *average* observations show that with paper and steel rolls and with *normal* pressure, 0.10 horsepower per inch face at 100 feet per minute is the average requirement. I would like to know what pressures Mr. Smith considered as normal pressures and whether he makes any distinction as to the number of rolls in the stack. The calender stacks have generally 9 to 11 rolls and it is my observation that the power requirement is a direct function of the number of nips in the stack as well as the speed and pressure.

With an up-to-date roller-bearing-equipped calender stack, the four variables are: speed, width, number of nips, and the *average* nip pressure per inch of width. These factors are all essentially linear. Figure 1 of this discussion shows the results of

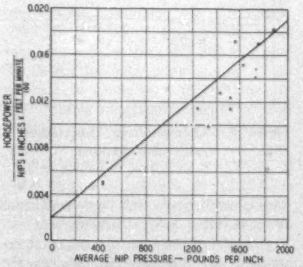

Figure 1. Supercalender power-pressure data, paper rolls

a number of observations correlated as to power requirements as a function of average nip pressure. The average nip pressure is taken, rather than the maximum pressure which occurs at the bottom nip, as being more indicative of the over-all operation of the stack.

These observations, taken on seven different arrangements of supercalenders, show a reasonably close co-ordination when plotted in this manner. If the supercalender which Mr. Smith first cited is assumed to be equipped with paper and steel rolls as were the rest of these, this point corresponds with the others.

Inasmuch as the usual supercalender stack has at least nine rolls, Mr. Smith's constant of 0.1 horsepower per inch face will give on this curve, a constant of 0.0125 horsepower per nip which would be equivalent to an average nip pressure of from 1,200 to 1,600 pounds per inch. The bottom nip pressure, which is more commonly used in expressing pressures, may be from 10 to 20 per cent higher than this.

If an 11-roll stack is assumed, the maximum pressure will be from 950 pounds to 1,350 pounds per inch nip. On this basis, it does not seem that this power constant is adequate for the modern calenders where pressures certainly do approach 2,000 pounds per inch face; furthermore, it appears that power is a very definite function of the number of rolls in the stack and this should be taken account of in general recommendations.

There is one other point worthy of comment and that is that my experience shows no great variation of power with respect to the weight of paper being used, but that the major variation is in the nip pressure. It is true that higher nip pressures may sometimes be used with the heavier grades of paper, but it is more likely that high nip pressures will be used where it is desired to obtain a highly finished paper at high calendering speeds. The finish obtained seems to be a function, not only of nip pressure, but of speed of operation. The paper as it passes through the stack is subjected to a steam bath and the finish depends upon the amount of moisture absorbed. Naturally, the slower the stack runs the more moisture will be absorbed and the higher the finish. A higher nip pressure can offset a reduction in moisture as far as finish is concerned and accordingly, the tendency is to use higher nip pressures to get an equivalent finish when high speeds are required.

Experience with supercalenders operating at speeds from 1,000 to 2,000 feet per minute is not yet extensive enough to indicate clearly definite relation between optimum nip pressure and operating speed. Some operators feel, as Mr. Smith points out, that the greatest pressures may be used at a relatively low speed while others indicate that the maximum pressure may be required to obtain a sufficient finish on any paper calendered at the maximum speed. A more complete investigation of this factor is desirable and in any case, specific knowledge or assumption in this connection is required to choose properly between the constant-field or adjustable-speed motors. Both types of drive operate successfully within their power limits.

The power data presented herein should be supplemented by further observations before any general recommendations are arrived at and it is hoped that interested operators will in the future present such data.

R. H. Smith: The calender cited with a power constant of 0.132 horsepower per inch face per 100 feet per minute is equipped with composition paper rolls. In the subsequent statement, referring to average observation, pressures in the order of 1,200 to 1,600 pounds per inch at the bottom nip were considered normal and a nine-roll calender was assumed.

Supercalendering operations are being carried on at higher pressures between the rolls and calender builders have been progressive in developing means for applying and controlling these higher pressures. The roll makers are called upon to provide composition paper and cotton rolls capable of withstanding these pressures without increased deformation and deterioration.

Anticipation of the load requirement of a calender does require consideration of operating pressures. Means for measuring pressures have been none too reliable, which factor, coupled with the variable of roll hardness and surface condition, seems to prevent establishing rigid rules for absolute power determination at this time.

Cold-Cathode Gas-Filled Tubes as Circuit Elements

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SINCE the discovery by Hull[1] that oxide-coated cathodes could be used as commercially practical thermionic emitters in gas-filled tubes, these tubes have found extensive use. For high-voltage d-c power supplies two-element mercury-vapor rectifiers have almost entirely replaced rotating machines and the earlier high-vacuum tube rectifiers. The addition of a grid to the gas-filled thermionic rectifier yields the thyratron which is used in regulated rectifiers, for the inversion of direct current to alternating current, and as a sensitive relay in numerous industrial control circuits. The discovery by Slepian and Ludwig[2] of the ignitor principle in initiating the arc spot on a mercury-pool cathode provided a ready means for controlling current flow in tubes with mercury-pool cathodes and the ignitron has now shown itself to have a large field of application.

The present paper will concern itself with gas-filled circuit elements of a third type, cold-cathode tubes. The principles of operation of these devices are not new[3] but their wide application has awaited the development of tubes which will operate in low-voltage circuits of, say, 150 volts or less.[4] Functionally, these tubes have much in common with thyratrons but their current-carrying capacity must remain limited because energy dissipation at the cathode of a glow discharge restricts the current which may be drawn without overheating the surface. However, as control devices in that large class of circuits where milliamperes rather than amperes are required, cold-cathode tubes are capable of performing many of the circuit functions of thyratrons and possess several major advantages over tubes of the hot-cathode type.

General Characteristics of the Glow Discharge

The properties of cold-cathode tubes in which we are interested follow immediately from the well-known characteristics of the self-sustaining glow discharge.

Consider two electrodes in a gas at a reduced pressure. If a low potential is applied between them the few ions which are always present in the gas become multiplied by secondary ionization resulting from impacts of the original electrons and ions with gas atoms and a small current flows through the tube. The gas conduction at this stage is known as the

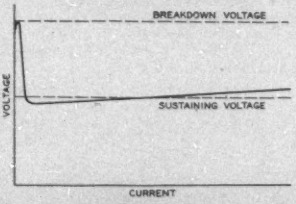

Figure 1. Current-voltage characteristic of typical glow discharge

Townsend discharge and the current which flows is called a Townsend current. It is generally of the order of a microampere or less. As the potential between the electrodes is increased the current increases and at some potential, the breakdown voltage, the gas becomes a good electrical conductor. The voltage across the electrodes now assumes a lower value, which we will call the sustaining voltage, at which it remains practically constant and independent of the current, the magnitude of the current being determined by the external resistance of the circuit. Figure 1 shows schematically the current-voltage characteristic of such a discharge tube.

Cold-Cathode-Tube Structure and Characteristics

Figure 2 shows a photograph of a typical cold-cathode tube. The structure consists of three elements, a cathode, an anode, and a control anode. The cathode is a nickel surface coated with a mixture of barium and strontium produced by reduction from the oxides of these metals by positive-ion bombardment in a glow discharge. The anode is a plain nickel wire shielded from the other elements except for its extreme end by a glass sleeve and separated from them by a spacing of about one-half inch. The control anode is placed close to the cathode. In the particular tube illustrated this element is identical with the cathode and therefore these two elements may be used interchangeably. Such construction, however, is not necessary and in other tubes the control anode may be a wire or small surface near the cathode. The gas filling is a mixture of the rare gases, 99 per cent neon—1 per cent argon at a pressure of about 40 millimeters of mercury. Variations in the constitution of this gas mixture may be used to control the electrical characteristics of the device. In such a three-element cold-cathode tube we have to deal with two conduction paths. That between the cathode and the main anode we will call the main gap and that between the cathode and the control anode the control gap. The nominal characteristics and ratings of this tube are given in table I.

Such a tube has many interesting properties as a circuit element. Basically it may be made to perform three distinct circuit functions, those of a relay, rectifier, and voltage regulator. We shall consider these in turn.

The Cold-Cathode Tube as a Relay

Figure 3 shows a typical cold-cathode-tube relay circuit. The supply potential must be greater than the main gap sustaining voltage but less than the main gap breakdown voltage so that no conduction will normally occur. If now a potential exceeding its breakdown voltage is applied to the control gap the resulting ionization will initiate conduction in the main gap and the anode potential will fall to the main gap sustaining voltage, the current being limited by the external circuit impedance. Conduction will continue until the circuit is opened or the anode voltage maintained below the main gap sustaining voltage for a sufficiently long time for the tube to deionize. The control gap current required to cause breakdown in the main gap we will call the transfer current. In magnitude it does not greatly exceed the Townsend currents flowing just below the breakdown voltage. For the tube described it is in general less than one

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1. For all numbered references, see list at end of paper.

microampere. The cold-cathode tube is thus a very sensitive relay.

The transfer current is a function of the anode voltage. It must obviously be zero at the main-gap breakdown voltage and approach infinity at the main-gap sustaining voltage. Figures 4*a* and *b* show the transfer-current characteristic of the tube illustrated in figure 2 with two different gas fillings Neon with a one per cent admixture of argon gives a very low transfer current. One hundred per cent argon gives a much higher transfer current and a higher main-gap breakdown voltage.

In using cold-cathode tubes as relays we must consider not only the amplitude of the signal, which together with the control-gap circuit impedance determines the current available for transfer of the discharge, but also its duration. For the Western Electric 313*C* tube it is found that signals of a duration of 200 microseconds are long enough to give reliable operation even when the amplitude of the signal is small. For signals of greater amplitude a shorter signal duration will suffice.

Figure 2. Cold-cathode relay tube

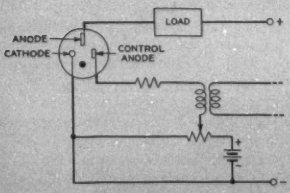
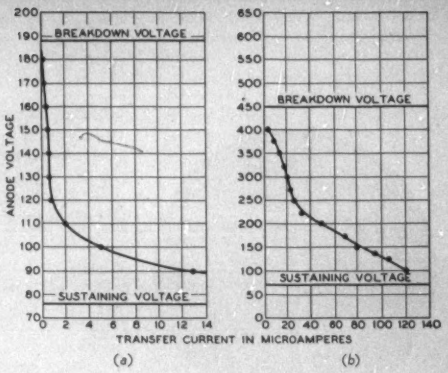


Figure 3. Cold-cathode-tube relay circuit

Figure 4. Transfer current characteristic of cold-cathode relay tube

(*a*)—Gas filling, 99 per cent neon, 1 per cent argon, 40 millimeters

(*b*)—Gas filling, 100 per cent argon, 15 millimeters



Deionization times are of the order of ten milliseconds, somewhat too long for satisfactory operation on 60 cycles. Tubes with shorter deionization times may be made by using gas filling of pure argon but this may be done only at the expense of increasing the transfer current. Thus while such tubes are faster in their operation as relays they are less sensitive.

The stability and reproducibility of tube characteristics are of interest in circuit design. The important characteristics are the control-gap breakdown and sustaining voltages and the main-gap sustaining voltage. The stability of the main-gap breakdown voltage may vary without detrimental effect on the circuits provided it does not fall to the supply voltage. Several years operating experience with tubes of the 313 type have shown that in general the three characteristics mentioned above will remain within plus or minus five volts of their initial values over several thousand hours of operating life if the current ratings are not exceeded. Deterioration of the tubes or shifts in characteristics on standing are negligible. Variations in initial characteristics will depend upon the degree of manufacturing control and, in general, will not exceed plus or minus ten volts.

One limitation on the use of glow discharges as relays should be noted. Oscillation, inherent in the glow itself, and resulting in "noise," makes gas tubes unsuitable to carry voice currents in communications circuits. This restriction, of course, applies to all other gas discharge devices including thyratrons. For control and signalling applications, however, this noise is unimportant.

The Cold-Cathode Tube as a Rectifier

The second circuit function which can be performed by means of cold-cathode tubes is rectification. Rectification requires an asymmetry in the current-voltage characteristic of the rectifying circuit element. When such an asymmetry exists a symmetrical voltage wave applied to the elements results in an asymmetrical current wave in the circuit. The cold-cathode-tube rectifier depends for its operation upon an asymmetrical property of the glow discharge itself. The sustaining voltage is primarily determined by the cathode fall of potential which in turn is largely dependent on the nature of the cathode material. In general low cathode falls are associated with surfaces of low work function. The slope of the current-voltage characteristic depends not only upon the nature of the cathode surface but also upon its

Table I. Characteristics and Ratings of Western Electric 313C Tube

Control-gap breakdown voltage	70 volts
Control-gap sustaining voltage	60 volts
Main-gap breakdown voltage	176 volts
Main-gap sustaining voltage	75 volts
Transfer current at anode voltage of 130 volts	5 microamperes, maximum
Deionization time	
Main gap	10 milliseconds
Control gap	3 milliseconds
Maximum instantaneous cathode current	30 milliamperes
Maximum average cathode current	10 milliamperes
Maximum time of averaging cathode current	1 second
Maximum instantaneous reverse current in main gap	5 milliamperes

area. A small cathode surface produces a steep characteristic. A glow-discharge tube then, with two electrodes one of which is large and coated with a material whose work function is low while the other

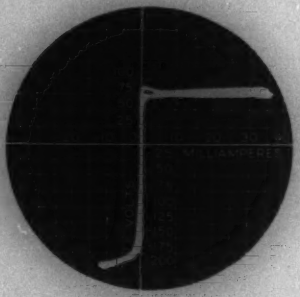


Figure 5. Asymmetrical current-voltage characteristic of cold-cathode rectifier tube

is small and uncoated, will have an asymmetrical characteristic.

The current-voltage characteristic of a Western Electric 313*C* tube connected as in the circuit of figure 6 is shown in figure 5. The trace was obtained by means of a cathode-ray oscillograph, the applied voltage being 208 volts root-mean-square, the load resistor, R_1, 5,000 ohms, and the control-gap resistor R_2, 100,000 ohms. The rectifying properties of the main gap are apparent from this characteristic. The control gap is connected into the circuit only to provide a low starting voltage in the forward direction.

Rectification can also be obtained using two-element tubes, the low starting voltage being produced by designing the tubes so that the anode-cathode spacing is small and the breakdown voltage therefore low. However, cathode sputtering from the small electrode on to the neighboring active surface causes the voltage characteristic of such tubes to be unstable so that three-element tubes are to be preferred.

As rectifiers cold-cathode tubes may be used either to convert an a-c power supply to direct current or to discriminate between positive and negative polarity in a circuit. In power supplies for radio receiving sets several tubes have attained some importance in the past,[6] although unsatisfactory tube life, radio-frequency noise arising from the discharge, and the inherent inefficiency resulting from the large voltage drop have prevented their wide adoption and in recent years their importance has been declining. As polarity detectors, however, cold-cathode tubes have a wide field of usefulness. One extensive application of this type in the communications field will be cited in the latter part of this paper.

The Cold-Cathode Tube as a Voltage Regulator

The voltage-regulating property of the glow discharge is well known. It is based upon the flatness of the current-voltage characteristic shown in figure 1. The sustaining voltage is practically independent of current. Thus in the circuits shown in figures 7*a* and *b* variations in the supply voltage will be practically entirely taken up in the series resistance, the voltage across the tube remaining constant.

Commercial voltage regulators are available which regulate at 60, 70, 90, 110, 130, and 150 volts. All such tubes may be operated in series to obtain regulation at higher voltages. The regulated voltage will in general vary less than five per cent from no load to full load and variations from tube to tube can usually be held to within ± five per cent of the nominal values. The tube illustrated in figure 2 may be used to regulate at either 60 or 75 volts, the sustaining voltages in the control and main gaps, respectively. The two circuit connections are illustrated in figures 7*a* and *b*. In the circuit of figure 7*b* the relay principle has been used to reduce the starting voltage exactly as it is when the tube is used for rectification.

Comparison of Ignitron, Thyratron, and Cold-Cathode Tube

In the introductory paragraph of this paper the functional similarity of the three types of gas-filled control tubes, thyratrons, ignitrons, and cold-cathode tubes, was stressed. These devices have this fundamental property in common. Each one contains a control element, the grid in the thyratron, the ignitor in the ignitron, and the control anode in the cold-cathode tube. Positive potential may in each case be applied to the anode without initiating gas conduction provided the control element is held more negative than some critical value. If, however, this critical value is exceeded, breakdown occurs and the gas becomes conducting. After conduction begins the control element loses all sensible control over the discharge which may be extinguished only by maintaining the anode below the sustaining voltage long enough for the tube to deionize.

Since they have these basic properties in common it is not surprising that the three types of gas-filled control tubes should be functionally similar in their circuit applications. It is scarcely too strong a statement to say that any *type* of circuit set up with one of these circuit elements can also be set up with either one of the others. In spite of this, however, they are not competitive with each other but rather complementary in their functions. This is because, while they are basically similar in principle, their operating characteristics are so widely

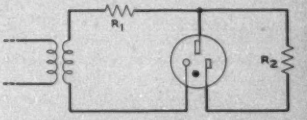


Figure 6. Cold-cathode-tube rectifier circuit

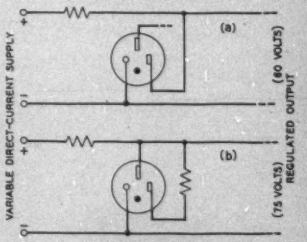


Figure 7. Cold-cathode-tube voltage-regulator circuits

different that generally in any particular case no doubt will exist as to which device is the *practical* one to use. Table II summarizes in a brief though necessarily incomplete way the comparative characteristics of the three classes of gas-filled control tubes.

The brevity of the table requires that something further be said in explanation.

In current-carrying capacity the ignitron is an inherently high-current device, the mercury-pool cathode being capable of supplying thousands of amperes of current. On the other hand, there exists a minimum current for stable operation, of approximately five amperes. Below this current the arc spot will not maintain itself. On the other end of the scale cold-cathode tubes are inherently low-current devices. At currents above about 20 milliamperes per square centimeter the active cathode surface is rapidly disintegrated by positive-ion bombardment. High current capacity then can be obtained only by the use of cathode areas

Table II. Comparison of Gas-Filled Control Tubes

Characteristics	Ignitron	Thyratron	Cold-Cathode Tube
Current capacity	5–10,000 amperes	Up to 100 amperes	Up to 100 milliamperes
Deionization time	10^{-4} second	10^{-4} second	10^{-3} second
Ionization time	10^{-4} second	10^{-6} second	10^{-4} second
Cathode heating time	0	Finite	0
Deterioration in standby service	No	Yes	No
Accuracy of characteristics	Variable	±2 volts	±10 volts
Sustaining voltage	15 volts	15 volts	75 volts

NOTE: Where specific values are given these are only approximate and are cited only to make a quick comparison possible.

of impractical size. Existing tubes are capable of supplying peak currents of approximately 100 milliamperes.

In speed of ionization and deionization the ignitron and the thyratron are much faster than the cold-cathode tube. This is because they are low-pressure devices. Argon-filled cold-cathode tubes are faster than those filled with neon-argon mixtures in which the neon predominates. The transfer currents, however, are also much higher so that in the argon-filled

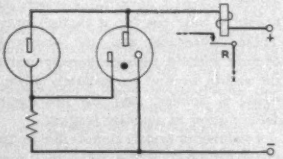


Figure 8. Photoelectric relay

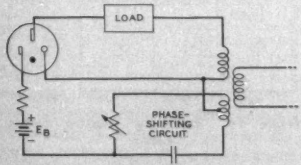


Figure 9. Cold-cathode-tube circuit with phase control

tubes sensitivity must be sacrificed in return for speed of operation.

The ignitron and the cold-cathode tube are, except for a brief ionization time, instant starting devices. The thyratron, on the other hand, requires a cathode heating time to bring the cathode to operating temperature. When the thyratron is used as a relay, the cathode must be maintained continuously at electron emitting temperature even though the periods of operation are brief and intermittent. This implies continuous deterioration of the tube even during standby periods. The necessity of supplying cathode power is itself a disadvantage. In service where the operation is intermittent much longer tube life is to be expected with cold-cathode tubes than with thyratrons.

As a voltage-operated device the thyratron is the most sensitive of the three. Its critical characteristic will generally be held within an extreme range of ± two volts. The variations in breakdown voltage of existing cold-cathode tubes will exceed this by a factor of five. Variability in ignitor rod materials causes ignitron characteristics to be most variable in this respect. For this reason an ignitron is generally controlled by an associated thyratron circuit so that the amplitude of the ignitor current may be made to exceed the critical value by a large margin while the thyratron is used as the voltage-sensitive element.

The sustaining voltage of the discharge is low, approximately equal to the ionization potential of the gas in both the ignitron and the thyratron. In the cold-cathode tube it is higher, approximately equal to the cathode fall of potential. This quantity is characteristic of the cathode material and the gas and is in general lowest for the alkalis and alkaline-earth metals associated with the rare gases. In practical applications the convenience of operation of the cold-cathode tube, since it requires neither filament transformer nor filament power, more than compensates for its lower efficiency resulting from high tube voltage drop.

Circuit Applications of Cold-Cathode Tubes

In cold-cathode-tube circuits as in thyratron circuits the problem of extinguishing the discharge, once it is initiated, must be met. The means available are four in number. The first is the use of an alternating anode voltage. After the removal of the control anode voltage conduction will then continue until the applied anode voltage falls to the sustaining voltage. Reignition will not occur on the next positive cycle if the frequency is low enough to allow the tube time to deionize. The second method is the opening of the anode circuit by a switch or relay contact. Again the length of the interruption must exceed the deionization time. The third is the application of a surge of negative voltage to the anode through a capacitor as in the familiar parallel type inverter circuit. The cold-cathode equivalent of this circuit is illustrated in figure 10 and will be described hereinafter. The fourth is the overshooting of the voltage due to the inductance of the circuit and the dynamic characteristic of the tube when a capacitor is discharged through it. This will be illustrated in considering the relaxation oscillator.

The basic relay, rectifier, and voltage-regulator circuits using cold-cathode tubes have been illustrated in figures 3, 6, and 7. Figure 8 shows a simple cold-cathode photocell relay. Increase of light intensity will cause the relay, R, to operate. Means will have to be provided for opening the anode circuit to reset the device for a second operation.

If an alternating voltage is applied to the anode of a cold-cathode tube and an alternating voltage of variable phase applied to the control anode, phase control of the output can be obtained. The circuit is shown in figure 9 and is quite analogous in its operation to phase-control circuits using thyratrons. The bias, E_B, on which the alternating voltage is superimposed should be somewhat lower than the control-gap sustaining voltage.

Figure 10 shows a cold-cathode-tube square-wave oscillator which is the ana-

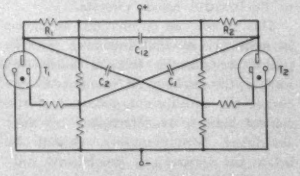


Figure 10. Square-wave oscillator

Note the similarity to the self-excited parallel-type thyratron inverter

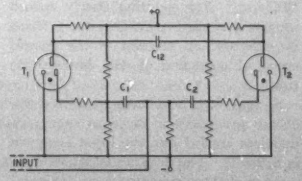


Figure 11. Counting circuit

Note the similarity to the Wynn-Williams "scale of two" circuit

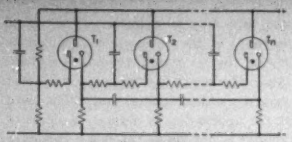


Figure 12. Chain counting circuit

logue of the self-excited parallel-type thyratron inverter. Such a circuit, of course, would not be used for the conversion of d-c power to a-c power since the cold-cathode tube is not a power device. It may be used, however, to generate a block wave to key another circuit. The operation of such a circuit is well known but will be described here since the principles are of general applicability in a variety of other circuits. Assume tube T_2 to be conducting, tube T_1 nonconducting. On the firing of T_1 its anode voltage will drop suddenly from the supply voltage to the sustaining voltage of the tube. This negative surge will be transmitted through the commutating capacitor C_{12}, extinguishing T_2 by driving its anode potential below the sustaining voltage and maintaining it there for a time determined by the time constant R_3C_{12}. A similar surge through C_2 reduces the control anode voltage of T_2 below the control gap breakdown voltage. C_2 charges up through the control gap resistors and T_2 fires when this voltage is again reached. The discharge will thus transfer back and forth between T_1 and T_2 at a rate dependent on the values of the constants in the control anode circuits.

This circuit can be modified as shown in figure 11 so that incoming positive pulses control the transfer back and forth of the discharge. Note that in this circuit the equilibrium potential of the control anodes, as determined by their associated potentiometers, should be below the control-gap breakdown voltage rather than above it as in the preceding circuit. The functioning of this circuit is analogous to that of the familiar "scale of two" counting circuit of Wynn-Williams.[6] For counting closely spaced impulses, of course, the thyratron circuit is preferable on account of the greater speed of operation of the hot-cathode tubes.

A chain of tubes, down which the discharge progresses in steps as successive impulses are fed into the input is shown in figure 12. The drop across the cathode resistor of the conducting tube "primes" the next tube in line so that it, rather than any other, is fired when the next impulse arrives. A potentiometer across tube T_1 gives its control anode an initial priming so that the first incoming pulse fires this tube preferentially. Detailed consideration of the behavior of thyratron circuits of this general class has been given recently by Shumard.[7]

Any glow discharge tube may be used in a relaxation-oscillator circuit. The simplest form of such a circuit is shown in figure 13. Oscillation will generally occur without the presence of the inductance L but its insertion causes the capacitor to discharge to a voltage well below the sustaining voltage rendering certain the extinction of the tube.

A novel use of cold-cathode tubes as relays in a device for the remote control

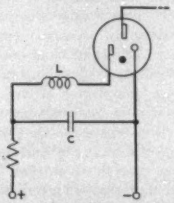


Figure 13. Simple gas-tube relaxation oscillator

of radio receivers has recently been described.[8] From a circuit standpoint the principal feature of interest in this circuit is the use of a radio-frequency signal on the control gap to fire the tube. As might be expected the peak voltage of the radio-frequency signal required to break the tube down exceeds the d-c control-gap breakdown voltage by a considerable margin.

What is probably the largest use of cold-cathode tubes to date is in an application in telephone communication where they have found extensive use in a four-party subscriber set for selective ringing.[9] The circuit is illustrated in figure 14. Of the four ringers, two are connected to one side of the line, two to the other, ground being used to complete the circuit. For selective operation of the two ringers on one side of the line a ringing signal is used which consists of an alternating voltage on which is superimposed a direct voltage. The cold-cathode tubes functioning as rectifiers are placed in series with the ringers and are oppositely poled in the two cases. One ringer responds to positive superimposed voltage, the other to negative.

One particularly valuable property of the tube in this application not possessed by rectifiers of other types is that as long as the breakdown voltage is not exceeded, the tube represents virtual open circuit to ground. Thus no transmission loss is experienced and no ground noise is introduced into the circuit when the line is used for voice transmission, the talking battery voltage having in general a nominal value of either 24 or 48 volts.

In the older type of equipment a-c relays were used to disconnect the ringers from the line except when ringing voltage was applied. Selection between the positive and negative polarities was obtained by means of mechanically biased ringers.

Summary

Three types of gas-filled control tubes are now in common use. The properties of cold-cathode tubes, the most recent of these to receive extensive application, have been considered and comparisons drawn with those of the more familiar thyratron and ignitron. It is concluded that in its own field of low-current control devices the cold-cathode tube has several inherent advantages which will ensure a wide use for it in the future. These advantages are, the ability to operate without cathode heating power, the ability to start immediately when a signal is applied, and the absence of deterioration in standby service.

A number of typical circuits illustrating the capabilities of the tubes as circuit elements have been described. Several of these are in commercial applications. One, involving some hundreds of thousands of tubes, has been operating for several years and proves beyond doubt that the cold-cathode tube is a valuable addition to the array of control devices available to the circuit engineer.

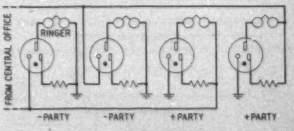


Figure 14. Four-party selective ringing circuit

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Polyphase Broadcasting

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THE universal use of amplitude modulation in radio broadcasting service has led to several formidable problems in the design of broadcast transmitting equipment. Improvements in technique which permitted the complete modulation of a carrier (100 per cent modulation) raised new problems in connection with the conversion efficiency of the final radio-frequency amplifier stage. Continued research has resulted in such developments as the high-level plate-modulated amplifier, the high-efficiency linear amplifier, outphasing modulation, and others.

In all of these high-efficiency systems, the radio-frequency output of the transmitter is amplitude modulated, and at 100 per cent modulation, the radio-frequency power output of the transmitter varies all the way from zero to four times the carrier power during each cycle of the audio-frequency modulating voltage. It is thus apparent that the final power-amplifier tubes must be capable of delivering a peak power equal to four times the carrier power of the transmitter.

The unique feature of the system to be described is the fact that the radio-frequency power output of the transmitter is constant throughout the audio-frequency modulation cycle, and is equal to $1^1/_2$ times the carrier power. This feature indicates the possibility of reducing the high-power tube complement to a very minimum, and it is conceivable that the peak power capacity of the final amplifier tubes might be as low as $1^1/_2$ times the carrier power instead of the twice carrier value of the present paper.

The comparison between the polyphase broadcasting system and the system of present-day broadcasting is somewhat similar to the comparison between a polyphase generator and a single-phase generator in that the instantaneous power output of a polyphase generator supplying a balanced load is constant, while in the case of the single-phase generator, the power varies sinusoidally from zero to twice the average power during the cycle.

It will be shown that the "rotating modulation field" essential to polyphase broadcasting may be obtained by the use of a five-element vertical antenna array. Four identical radiators are arranged at the corners of a square with the fifth antenna in the center. The central antenna is supplied with unmodulated radio-frequency power and is called the carrier antenna. The antennas at opposite ends of one diagonal constitute a directional pair and are supplied with suppressed-carrier modulated radio-frequency power. The two antennas at the ends of the other diagonal also constitute a directional pair and are fed with suppressed-carrier modulated radio-frequency power. The two antennas of each side-band pair are fed in series and carry currents of opposite phase, so that the directional patterns are figures of eight at right angles. Further, the phase of the suppressed-carrier currents in the side-band pairs differs from the phase of the current in the carrier antenna by an angle of 90 degrees. If in addition, the modulating voltage in the suppressed carrier channels is in quadrature, the required conditions, for a rotating modulation field, are fulfilled.

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The Radiating System

The fundamental arrangement of the antenna system is shown in figure 1. The antenna at the point O is the carrier antenna. The antennas 1 and 1′ comprise a directional pair, and carry equal and opposite double side-band currents. Similarly, antennas 2 and 2′ comprise a directional pair and are placed physically at right angles to the first pair.

Let the following currents be established in the antenna system:

$$i_0 = I_0 \cos \omega t \quad \text{(carrier)}$$
$$i_1 = I_1 \sin \omega t \sin \rho t \quad \text{(double side band)}$$
$$i_{1'} = -I_1 \sin \omega t \sin \rho t \quad \text{(double side band)}$$
$$i_2 = I_1 \sin \omega t \cos \rho t \quad \text{(double side band)}$$
$$i_{2'} = -I_1 \sin \omega t \cos \rho t \quad \text{(double side band)}$$

where

i_0 = instantaneous current in antenna O
i_1 = instantaneous current in antenna 1
$i_{1'}$ = instantaneous current in antenna 1′
i_2 = instantaneous current in antenna 2
$i_{2'}$ = instantaneous current in antenna 2′
ω = 2π times carrier frequency
ρ = 2π times modulating frequency
I_0 = maximum value of current in carrier antenna
I_1 = maximum value of current in side band antennas

The field intensity E at a remote point P, with arbitrary reference angle θ and at a distance r_0 meters from the central antenna, becomes:

$$E = \frac{KI_0}{r_0} \cos \omega \left(t - \frac{r_0}{C} \right) +$$
$$\frac{KI_1}{r_0} \left\{ \sin \omega \left(t - \frac{r_0 - d \cos \theta}{C} \right) - \sin \omega \left(t - \frac{r_0 + d \cos \theta}{C} \right) \right\} \sin \rho t +$$
$$\frac{KI_1}{r_0} \left\{ \sin \omega \left(t - \frac{r_0 + d \sin \theta}{C} \right) - \sin \omega \left(t - \frac{r_0 - d \sin \theta}{C} \right) \right\} \cos \rho t$$

Where K is an antenna performance constant, all antennas assumed identical, C is the velocity of light in meters per second.

The above expression after some reduction, becomes:

$$E = \frac{KI_0}{r_0} \cos \omega \left(t - \frac{r_0}{C} \right) \left[1 + \frac{2I_1}{I_0} \times \left\{ \sin \left(\frac{\omega d \cos \theta}{C} \right) \sin \rho t - \sin \left(\frac{\omega d \sin \theta}{C} \right) \cos \rho t \right\} \right]$$

Now, if the spacing of the antennas be restricted so that $\sin (\omega d/c)$ differs only slightly from $\omega d/c$, we have approximately

$$E = \frac{KI_0}{r_0} \cos \omega \left(t - \frac{r_0}{C} \right) \times \left[1 + \frac{2\omega d I_1}{CI_0} \sin (\rho t - \theta) \right] \quad (1)$$

Inspection of equation 1 shows that the

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6. A THYRATRON "SCALE OF TWO" AUTOMATIC COUNTER, C. E. Wynn-Williams. Royal Society *Proceedings*, series *A*, volume 136, 1932, pages 312–24.

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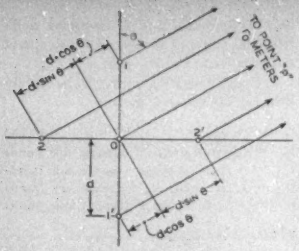


Figure 1. Antenna plan

field intensity at the point P is amplitude modulated, and that the phase of the modulation varies as the azimuth angle θ.

The modulation may be said to be 100 per cent when $(2\,\omega d I_1)/(c\,I_0) = 1$.

Further, the value of I_1, the maximum value of current in the side-band antennas is, for 100 per cent modulation

$$I_1 = \frac{C}{2\omega d} I_0$$

$\frac{\omega d}{C}$ is the antenna spacing in radians S

Hence

$$I_1 = \frac{I_0}{2S}$$

Thus, for a spacing of one-half radian, the maximum side-band antenna current is equal to the maximum carrier antenna current in the 100 per cent modulated condition.

Referring again to figure 1, the following items should be noted:

1. Radiators 1 and 1′, since they carry equal and opposite currents, induce no voltage in antennas O, 2, or 2′.

2. Radiators 2 and 2′, since they also carry equal and opposite currents, induce no voltage in antennas O, 1, or 1′.

3. Radiator O induces equal voltages in antennas 1 and 1′, and 2 and 2′. Inasmuch as these antenna pairs are fed in series, the induced voltages are in opposition, and thus produce no current.

The full significance of the above points is grasped when it is realized that the carrier antenna, side-band pair 1, 1′, and side-band pair, 2, 2′, are completely decoupled, and each may be fed by its own generator (amplifier) without affecting the others.

In the derivation of the expression for the field intensity at the point P, the formula was simplified by making the assumption that the electrical spacing was small, less than 0.5 radian. This consideration is fortunate, for in practice it means that the side-band radiators can conceivably be suspended from the main carrier radiator. For example, with a spacing of one-third radian, the following situation exists at a frequency of 1,000 kilocycles:

One wave length = 985 feet
One-third radian = 52.2 feet

The required spacing is thus 52.2 feet, which is an entirely feasible value, permitting the central radiator to support the side-band radiators.

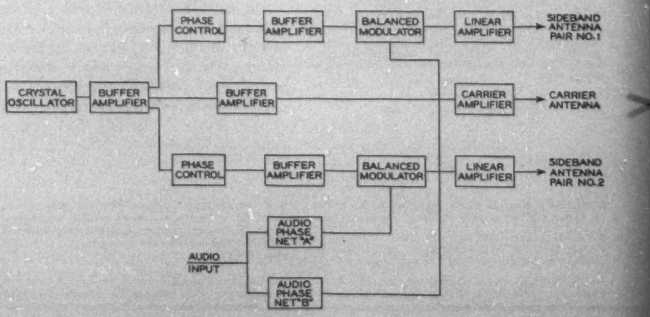
Another desirable result of the close spacing is that the high-angle radiation distribution of the side-band system closely approaches that of the central antenna, so that the per-cent modulation is substantially equal for all radiation angles.

The spacing, however, must not become too small, for some difficulty would undoubtedly be experienced, first in the balance of the mutual effects of the independent systems, and second, the radiation resistance of the side-band pairs at the current loop diminishes approximately as the square of the spacing. For a spacing of one-third radian, the resistance at the current loop for the side-band pairs may be calculated to be 22.2 per cent of that of the central antenna. It is a rather simple matter properly to excite this side-band system.

The Transmitter

A block diagram of a typical polyphase transmitter is shown in figure 2. It is essentially a three-channel transmitter frequency-controlled from a common crystal oscillator and appropriate buffer amplifiers. The carrier channel is a straightforward continuous-wave telegraph design and sufficient amplifiers cascaded to obtain the desired carrier power level. The output of the carrier amplifier is coupled by conventional means to the carrier antenna. Each of the side-band channels consists of a final class-B radio-frequency amplifier excited by a balanced modulator. The balanced modulator, in turn, receives its excitation from the crystal oscillator through a phase-shifting goniometer, and the necessary buffer amplifiers. The output of each side-band channel is fed to the appropriate pair of side-band radiators. The phase-shifting goniometer is employed in each of the side-band channels to provide easy adjustment of phase so that the phase of the double side-band current in the side-band antennas can be set at its proper value with respect to the radio-frequency current in the carrier antenna.

Figure 2. Block diagram of polyphase transmitter



Polyphase Audio System

All of the foregoing material would be an interesting academic consideration only, if it were impossible to design a satisfactory source of two-phase audio-frequency modulating voltage. Two possible systems were studied.

The first system given consideration was the following. A single-side-band signal is obtained using a 50-kilocycle suppressed-carrier modulator and appropriate filters. The resulting single-side-band signal is impressed on the grids of two demodulators, one demodulator being supplied with the original carrier, and the other with the original carrier shifted 90 degrees in phase. The outputs of the demodulators will be in phase quadrature. This system, while producing perfect quadrature voltages, is seriously limited in its low-frequency response due to the nature of the filters required. The limitation is so severe, that the best single-side-band systems today are acceptable only between frequencies of 100 and 6,000 cycles. This frequency

band is not sufficient for high-fidelity broadcasting, and consequently, this source of two-phase audio was discarded.

The second system, and the one adopted, makes use of non-dissipative phase-delay networks of the lattice type. The audio-frequency voltage is impressed across two networks, each having three sections, and the circuit constants in each section are so chosen that the *difference* in the phase delay of the two networks is substantially 90 degrees throughout the frequency range 30–10,000 cycles.

Figure 3 is the calculated and measured performance of a pair of two-section networks. In this graph, the deviation from the desired value of 90 degrees is shown as a function of frequency. Figure 4 is the calculated performance of a pair of three-section networks.

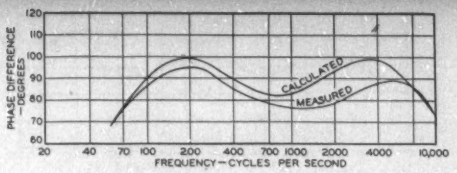


Figure 3. Performance of a pair of two-section phase-shifting networks

Practical Aspects of the System

Vacuum-Tube Complement

It is clear that, for a 50-kw transmitter, the carrier amplifier must be capable of supplying a peak power of 50 kw. Under no condition is its load any greater than 50 kw. Further, at 100 per cent modulation, the power output of the system is constant at $1^1/_2$ times carrier power.

The combined output of the side-band amplifiers is hence equal to one-half the carrier at every instant of the 100 per cent modulation cycle. Each of the side-band pairs is idle twice every cycle and during this time the operating side-band pair must supply all the side-band power. It is therefore apparent that the side-band amplifiers *each* have a peak capability of one-half carrier power. In the case of a 50-kw transmitter, therefore, each side-band linear amplifier must have a peak capacity of 25 kw.

The total tube capacity in the final stage of the transmitter is hence equal to two times the carrier power, in contrast with four times carrier power in present day equipment.

The reduction in the number of vacuum tubes required in the final stage of a high-power transmitter is at once apparent. Comparing a possible arrangement for a 500-kw polyphase transmitter with the arrangement at WLW, it can be shown that at least 11 of the 20 100-kw vacuum tubes now used would be eliminated. The saving in filament power consumption alone, would be of the order of 80 kw.

Efficiency of Final Amplifiers

The efficiency of the carrier amplifier will be nominally 70 per cent so that in the case of a 50-kw transmitter, the plate input to this stage will be 71.4 kw. In the case of the side-band amplifiers, assume that the peak efficiency during a modulation cycle is 70 per cent. This efficiency will be obtained at the maximum output of 25 kw. Assuming that the plate current of the linear amplifier is proportional to the radio-frequency grid voltage, the instantaneous power input p will be

$$p = E_B I_B |\sin \rho t|$$

where E_B = direct plate voltage in kilovolts, I_B = maximum value of plate current in amperes. The d-c input power P is the average of the above expression.

$$P = \frac{2E_B I_B}{\pi}$$

Also it was assumed that, for 25-kw peak output, the efficiency was 70 per cent. Therefore

$$E_B I_B \times 0.7 = 25$$

The average power input to each side-band amplifier is thus

$$P = \frac{2 \times 25}{\pi \times 0.7} = 22.7 \text{ kw}$$

The average output of each side-band amplifier is 12.5 kw and the efficiency is $12.5/22.7 = 55$ per cent.

At 100 per cent modulation, the total power input to the last stages is

Carrier amplifier	71.4 kw
Side-band amplifier number 1	22.7 kw
Side-band amplifier number 2	22.7 kw
Total	116.8 kw

The output, 100 per cent modulated, is 75 kw and the efficiency of conversion is $75/116.8 = 64$ per cent. This efficiency figure is comparable to other high-efficiency systems.

Exciter Circuit Requirements

In the case of the high-efficiency linear amplifier, the exciter circuit must be of sufficient capacity to drive the final amplifier to a peak output of four times carrier power. For example, in the case of a 50-kw transmitter, the exciter must be capable of substantially linear performance for a final amplifier output range, 0 to 200 kw. In the polyphase system, however, each side-band amplifier exciter is required to drive its amplifier linearly only in the range 0 to 25 kw. This fact results in a reduction in exciter capacity, and in fact, radiation-cooled tubes may readily be used for excitation of the final amplifiers for 50-kw transmitters. The exciter for the carrier amplifier may likewise consist of radiation-cooled tubes. Inasmuch as the total capability of the final amplifiers is only one-half as great as in conventional systems, the exciter capability is likewise half as large as is ordinarily required. As a matter of fact, the exciter capacity is somewhat less than one-half that required for a linear amplifier, for it is unnecessary to provide a stabilizing load for the carrier amplifier exciter.

Fidelity of Transmission

The effect of the phase of the audio signals being different from 90 degrees results in nonuniform percentage of modulation in different directions. Equation 1 was derived on the assumption that the audio-frequency modulating voltage was in phase quadrature. If the audio-frequency voltages are not in phase quadrature, the expression for the field is modified according to the following expression:

$$E = \frac{KI_0}{r_0} \cos \omega \left(t - \frac{r_0}{C} \right) \left[1 + \frac{2SI_1}{I_0} \times \left\{ \sin \rho t \cos \theta - \cos (\rho t - \phi) \sin \theta \right\} \right]$$

where ϕ is the deviation from the desired 90 degrees.

Inspection of this relation shows that the greatest effect due to phase deviation will occur for $\theta = 45$ degrees, 135 degrees, 225 degrees, and 315 degrees.

The following table shows the effect of small deviations upon the per-cent modulation at an angle $\theta = 45$ degrees.

Phase Deviation	Decibel Change in Amplitude
+10	−0.82
+ 5	−0.38
0	0
− 5	+0.36
−10	+0.68

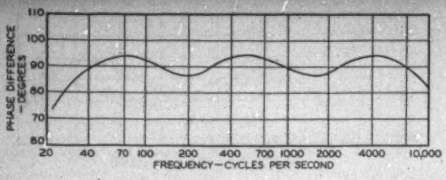


Figure 4. Performance of a pair of three-section phase-shifting networks

The change in modulation level for small deviations from the desired value of 90 degrees is thus seen to be small.

If the phase relation between the audio signals is different for signal components of different frequencies, the result in any particular direction is the same as that produced by varying frequency response in the conventional transmitter. As noted above, if the phase does not vary from 90 degrees by more than ± 10 degrees the effect is a maximum variation in frequency response of less than one decibel. Thus a deviation from the desired 90-degree phase relation of the modulating voltages produces frequency distortion.

The effect of an improper phase adjustment of the side-band amplifiers with respect to the carrier is to produce amplitude distortion. To make this clear refer to figure 5. In this figure the line OC is the carrier vector. The side-band vectors are oppositely rotating and their sum lies along the line $S-, S+$. At any particular instant in the modulation cycle the sum of the carrier and the two side-band vectors might be represented by the vector OP. As the modulation progresses through the cycle, the point P moves back and forth along the line $S-, S-$ in simple harmonic motion. A linear detector would merely provide a current proportional to the magnitude of the vector OP as a function of time. Consequently if the side-band phase is incorrect by as much as 30 degrees serious amplitude distortion would occur at high modulation percentages, for the length of the vector OP obviously does not vary sinusoidally. On the other hand, if the side-band phase is no more than three degrees from the desired value, a glance at figure 5 is sufficient to indicate that the amount of distortion occurring would be rather small. In practice, a remote monitoring point would be selected, and the modulated radio-frequency pattern would be transmitted back to the control point at a low intermediate frequency—say 50 kilocycles. This pattern would then be viewed on a cathode-ray oscilloscope and proper adjustment of the phase of the side-band amplifiers with respect to the carrier would permit full 100 per cent modulation to be obtained.

Experimental Data

A systematic program of experimental work is in progress to substantiate the fundamental operations of the system

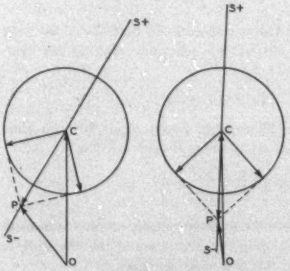


Figure 5. The effect of side-band phase adjustment

and to make a detailed study of broadcast-signal fidelity.

The first preliminary work was carried out with a transmitter having about 100 watts carrier power and operating on about 80 meters. Preliminary measurements showed complete accord with the above theory of operation. A check was made using two-phase 60-cycle audio frequency for modulation of the transmitter and 60 cycles from the same source was used to modulate a second conventional transmitter on a different frequency. By the use of two similar receivers the demodulated 60-cycle output from the two receivers was compared, and the phase between these two outputs varied from 0 to 360 degrees as the receiving point was moved around the antenna system.

The audio-frequency phase-difference network of figure 2 was then inserted and the polyphase transmitter operated on voice modulation. The fidelity of operation was equivalent to that of conventional transmitters. No particular attempt was made in these first experiments to measure audio-frequency harmonic distortion or to make a detailed study of fidelity. No effort was made to provide an accurately spaced antenna system or to provide low-distortion suppressed-carrier modulators in this first model.

In order to make a detailed experimental study of the broadcast signal fidelity, a second project is under way. This project consists in construction of a 1,000-watt broadcast-frequency transmitter. Experimental data will be obtained using an array of half-wave vertical radiators.

Conclusions

A new system of broadcasting amplitude-modulated radio-frequency signals has been described. It is felt that this system has great possibilities and the essential features are high efficiency of power conversion and minimum tube capacity requirements for the final amplifiers. The inherent disadvantage of such a system lies in the fact that an essential requirement is a nondirectional radiation pattern. It is felt that the complication of circuits and adjustments over that of conventional transmitters will further limit the application of this system to high powered equipment (50 kw and larger) where power consumption and tube replacement are formidable items of expense.

The technical possibility of superpower transmitting equipment of the order of 1,000 to 2,000 kw, is brought into the realm of reality using tubes now available.

A 12-Channel Carrier Telephone System for Open-Wire Lines

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MEMBER AIEE

Synopsis: A new carrier telephone system is described, together with its application in the long-distance telephone plant. By its use, an open-wire pair which already furnishes one voice circuit and three carrier circuits may have 12 more telephone circuits added. Thus in all 16 telephone circuits are obtained on a single pair. Several such systems may be operated on a pole line.

Various problems incident to the extension of the frequency range, from about 30 kilocycles, the highest frequency previously used, to above 140 kilocycles, are discussed. Among the more important of these are the control of crosstalk between several systems on a pole line, arrangements for taking care of intermediate and terminal cables, and automatic means for compensating for the effects of weather variations on the transmission over this wide frequency range.

BARE WIRES supported on insulators, stretched between poles, make up the pioneer electrical communication circuit, the open-wire line. Although great advances have been made in the application of cable structures, the open-wire lines still hold their own in some sections of the country. This is because, to offset their physical vulnerability, they have several unique virtues. They are flexible and permit adding one pair of wires at a time. They are also comparatively economical where conditions favor their use. Furthermore they are low-attenuation circuits and for this reason were the first to be used for high-frequency carrier systems.

The first carrier systems, beginning in 1918, added three or four channels to the existing voice circuit on a pair. To keep pace with this development, improvements in transposition systems were devised so that many such carrier systems might be operated on the same pole line. Such carrier systems, typified by the three-channel type C[1,2] system, have seen continuous growth in use in the long-distance plant. Now a 12-channel system, the type J, is being made available to add to the type C system, thus giving 16 telephone circuits on an open-wire pair in addition to the two telegraph circuits. Since there are already about 60,000 miles of pole line equipped with type C systems, the new type J system was developed to go in the frequency range above the type C system rather than to supersede it with more channels (figure 1).

The new system has been designed to meet high standards of transmission and reliability for distances up to several thousand miles. The frequency band transmitted by the individual derived circuits is exceptionally wide, from about 100 to 3,600 cycles for a single system and has been previously discussed[3] in relation to the channel spacing in this and other new broad-band developments.

An important feature of the work on the type J system has naturally been that of making the line circuits suitable for carrying the higher frequencies. The tendency of circuits to crosstalk into one another increases rapidly with frequency. Advances in transposition design and structural improvements have now made it possible to extend the frequency range from 30,000 cycles to 140,000 cycles, which is about the upper frequency of the type J system. The problem of incidental cables in open-wire lines has also been serious, since the losses increase with frequency, and what is usually more important, there may be substantial reflection effects at junctions of the open-wire line and cable. These are serious, not only from the standpoint of the transmission loss which they entail, but from their effect on crosstalk. The increase in attenuation at the higher frequencies has also brought other problems into the picture. For example, repeaters are needed at more frequent intervals than with the lower-frequency systems. Attenuation variation with frequency due to weather changes is greater than at the lower frequencies.

Figure 2 shows schematically the complete type J system, with its different major circuit elements, resulting at the terminals in the division of the single line circuit effectively into 16 talking circuits. In no recent development is the function of the wave filter in providing essential units in a frequency dividing plan more forcefully illustrated than in the application of this new system, in combination with the type C and other facilities which exist. There are about 60 different designs of filters and networks in the terminals and repeaters. Their functions are varied, as, for example, separating the individual channel bands, separating the opposite directional groups of channels, separating the type J frequency range as shown in figure 1 from the type C and other ranges, separating the different carrier frequencies of a carrier supply system in which the carriers are all derived from a common 4,000-cycle source, etc.

The new system, as in the case of the type C, uses single-sideband transmission with carrier elimination. Copper-oxide units are employed as translator elements of various kinds—modulators, demodulators, and harmonic producers. Methods of mounting the equipment, and methods and apparatus for testing follow lines already worked out for the type K cable carrier system, which was described a year ago in two AIEE papers.[4,5]

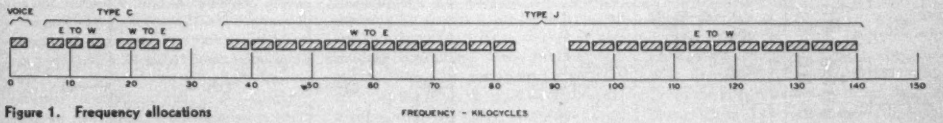

Figure 1. Frequency allocations

Channel Terminals

A terminal of the type J system changes 12 independent voice channels into a compact block of 12 carrier channels

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1. For all numbered references, see list at end of paper.

properly allocated in frequency for transmission over the open-wire line. Inversely, such a block received from the open-wire line is separated and transformed into 12 independent voice channels. The first step in transmitting the 12 voice channels is to modulate them on 12 carrier frequencies 4 kilocycles apart from 64 to 108 kilocycles and to select the lower sidebands by means of quartz-crystal channel band filters. The last step in the conversion from a received 12-channel block to the 12 independent voice channels consists in the division of the block by 12 quartz-crystal channel filters and the demodulation of these messages to produce voice frequency transmissions. These two frequency changes and separations are performed by the same equipment that is used in the type *K* cable carrier system terminals.

Figure 3 shows the circuit of a modulator and a demodulator for the opposite directions of a single conversation with indicated connections for the 11 others which make up this fundamental 12-channel block. The modulator consists of a bridge assembly of copper-oxide varistors and is supplied with about 0.5 milliwatt of carrier power from the carrier supply system which is described later. Of the two resulting sidebands, the lower is selected by the crystal band filter following the modulator. The line sides of 12 modulator band filters are joined in parallel and a compensating network is connected to preserve the band characteristics of the upper and lower channels.

On the receiving side, after separation by one of the 12 parallel filters, the side band is applied to a demodulator supplied with the proper carrier frequency to restore the voice-frequency message. Because of the low level at which demodulation takes place, the demodulator is followed by a single-stage amplifier to produce the level desired in the voice-frequency circuit. The gain of the amplifier is adjustable over a moderate range.

The combination of a single modulator and a single demodulator and associated equipment shown in figure 3 is called a "modem" and two of these are mounted on a single equipment panel. Nine of these panels, sufficient for $1^1/_2$ type *J* systems, or 18 conversations, mount in a single relay rack bay of standard height.

Carrier Supply

The carrier frequencies 64–108 kilocycles are all derived as harmonics of a 4-kilocycle frequency produced by a tuning-fork-controlled oscillator. This frequency is applied to an easily saturated coil to produce a sharply peaked wave which is rich in odd harmonics. Even harmonics of four kilocycles are obtained by rectification in a copper-oxide unit of part of the odd harmonic output. Odd and even harmonics appear in separate circuits from which each frequency desired is separated by a quartz-crystal filter. Frequencies as high as the 121st harmonic, that is, 484 kilocycles, are obtained in this way from the carrier supply system. Because of the importance of the carrier supply two sources are provided, with automatic equipment to transfer rapidly from the regular to the emergency source.

Group Modulation

As shown in figure 1, the type *J* system uses a band of 36 to 84 kilocycles for the west to east direction of transmission and 92 to 140 kilocycles for the east to west direction. The output of the fundamen-

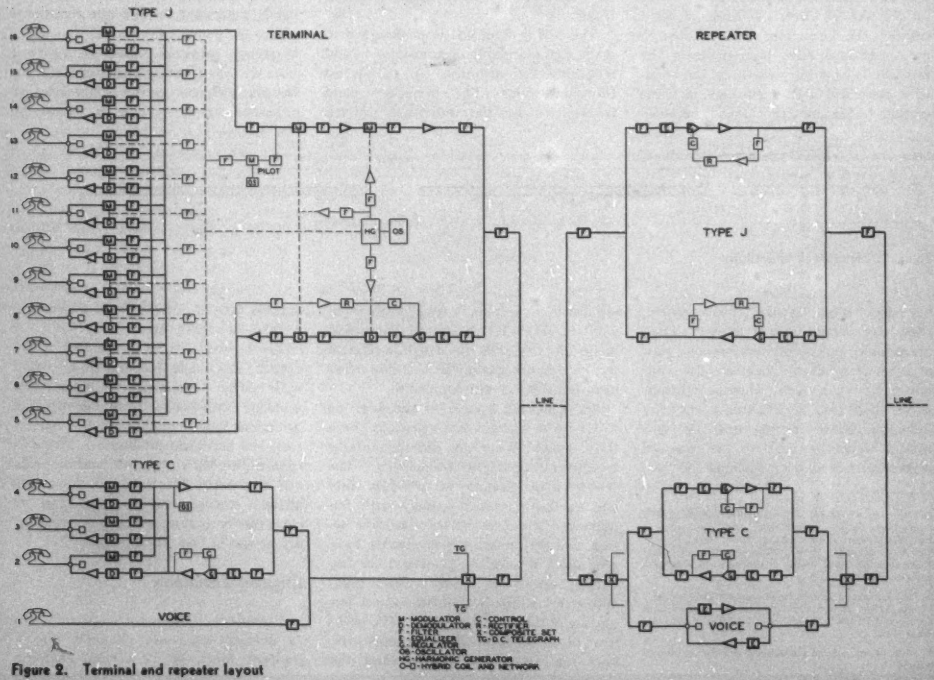


Figure 2. Terminal and repeater layout

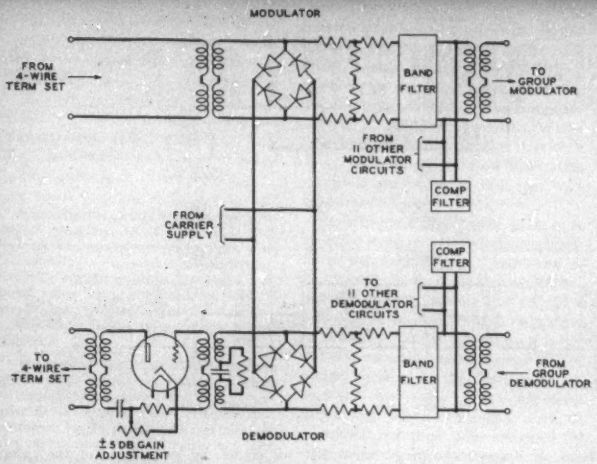


Figure 3. Channel modulator and demodulator

tal 12-channel unit consists of 12 lower sidebands from carriers of 64–108 kilocycles. This must, therefore, be translated to the two type *J* directional groups for line transmission. Since the frequencies in the fundamental unit overlap those in both directions of line transmission, this transfer must be made in two steps. Figure 4 shows these frequency translations. The first group modulation is the same for both directions of transmission. By modulating the fundamental unit with a carrier of 340 kilocycles there is obtained a block of lower sidebands extending from 400 to 448 kilocycles. A second modulation with a 484-kilocycle carrier then gives, for transmission from west to east, a 12-channel block of upper sidebands extending from 36 to 84 kilocycles. For the east to west transmission the second modulation uses a 308-kilocycle carrier, producing a 12-channel block of lower sidebands between 92 and 140 kilocycles.

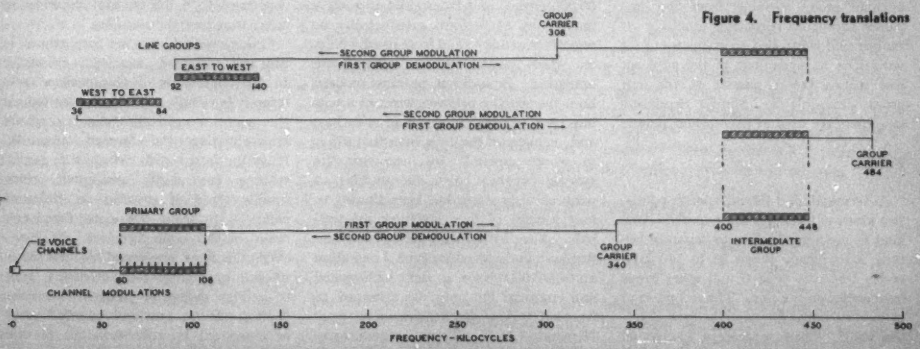
Frequencies as high as 308, 340, and 484 kilocycles are chosen for group modulation in order that undesired products shall be well separated from desired products to permit their elimination by simple filter structures.

The same group modulation processes that have been described above for adapting the 12-channel group for line transmission are used in the opposite sequence for receiving the block from the line and preparing it for separation by the channel band filters of the receiving terminal; thus, for instance, at an east terminal the block of upper sidebands, extending from 36 to 84 kilocycles as received from the line, is first modulated with 484 kilocycles producing lower sidebands between 400 and 448 kilocycles. These are next modulated with 340 kilocycles which produces a block of 12 lower sidebands extending from 60 to 108 kilocycles, which is the group that the fundamental 12-channel terminal unit is designed to handle.

Figure 5 shows the essential features of the group modulating and group demodulating circuits. As in the type *K* system, group modulation is performed at a very low level of the message material and with a high level, about 25 milliwatts, of the group carrier supply, in order to minimize interchannel crosstalk. The group modulators are of the doubly balanced bridge type which aids in suppressing some of the unwanted modulation products. Following the first group modulator and also following the first group demodulator are coil and capacitor type 400–448 kilocycle band filters which reject the unwanted products and pass the band of frequencies containing the 12 channels. Between this filter and the second group modulator on the transmitting side of the terminal, an intermediate amplifier is used in order to keep the level of the group transmission above danger of noise. Following the second group modulator and also following the second group demodulator are low-pass filters which cut off frequencies above about 160 kilocycles, to suppress unwanted modulation products. From the output of the receiving low-pass filter the 12-channel group, 60–108 kilocycles, passes through a two-stage "auxiliary" amplifier to bring it to the desired level.

The carrier frequencies for group modulation and for group demodulation are derived from the same four-kilocycle tuning-fork-controlled oscillator that supplies carriers for the 12-channel unit. From the circuit in which appear the odd harmonics of 4 kilocycles, the 77th, 85th, and 121st harmonics, that is, 308, 340, and 484 kilocycles, are selected by carrier

Figure 4. Frequency translations



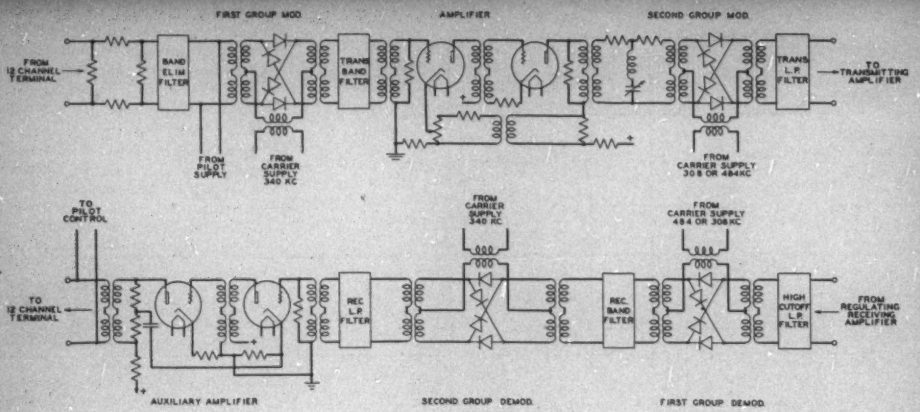


Figure 5. Group modulator and demodulator

supply filters and separately amplified by two-stage amplifiers to produce the powers required for group modulation. Outputs from these amplifiers are fed to individual-frequency busses capable of supplying the group modulators and demodulators for ten systems. An emergency carrier supply for these frequencies is also provided with arrangements for switching rapidly from the regular to the emergency circuits.

Terminal Amplifiers

As indicated on figure 5, the transmitted 12-channel group, now transferred to the proper frequency range for line transmission, goes from the low-pass filter at the output of the second group modulator to a transmitting terminal amplifier which is similar in most essentials to the amplifiers of the line repeaters. The 12-channel group arriving from the line passes through a regulating amplifier arranged and controlled to compensate for variations in equivalent of the adjacent line section before passing to the first group demodulator. Similar regulating amplifiers are used at all repeater points.

Filters

At terminals and also at repeater points, two kinds of filter sets are required. One kind is used in the line to separate the type *J* frequency range 36 to 140 kilocycles from the type *C* and other lower frequencies on the line. The second kind is the directional filters of the type *J* system itself. These separate a 12-channel band of frequencies lying below 84 kilocycles used for west to east transmission from the 12-channel group lying above 92 kilocycles which is transmitted from east to west. These directional filter sets are carefully designed to equalize any nonuniformity of loss in both the directional and the line filters. As this equalization involves a considerable loss over a large part of the filter band it is provided entirely in the receiving directional filters where the transmission is at a low level and the loss can readily be made up by amplification. In this way nearly the full energy output of the transmitting or repeater amplifier is available for line transmission.

Line Crosstalk Problems

As noted previously, type *J* systems will, in general, be applied on pairs on which type *C* systems are already operating. Such pairs have already been arranged to transmit frequencies up to 30,000 cycles, and transposed in such a manner as to perform satisfactorily as regards crosstalk to and from nearby pairs on which similar carrier systems are operating. In addition, on most modern lines the spacing between wires of a pair has been reduced from 12 to 8 inches; and, on many of the lines, in order further to reduce crosstalk by increasing the spacing between pairs, the number of pairs on a crossarm has been limited to four instead of five, omitting the pole pair. Now, by applying a new transposition system designed for type *J* operation up to 140,000 cycles, an eight-inch-spaced four-crossarm line may be arranged to transmit type *J* frequencies on at least 10 pairs out of 16. Type *C* systems may, of course, be used on all of the pairs. Finally by using the most advanced transposition design methods, and increasing the crossarm spacing, in addition to the features noted above, a new line may be constructed to permit the operation of 16 channels on all pairs.

To make the pairs of wires good for type *J* systems, more than a fourfold increase in frequency range, was difficult. The natural tendency of the circuits to crosstalk is increased even more than the frequency ratio, so that in addition to applying a new transposition design it is necessary that the transposition poles be more accurately located, and that the sags of the two wires of each pair be kept more nearly alike. On lines which already have eight-inch-spaced wires, no major structural changes are necessary. However, on lines which have only 12-inch-spaced wires and where it is desired to make available a number of pairs for type *J* transmission, structural changes, such as respacing the wires of the pairs concerned to 6 inches, are necessary in order to reduce the coupling.

One factor of extreme importance is that of reflected near-end crosstalk. In the application of transposition systems it is usually not possible to reduce the near-end crosstalk to a magnitude approximating the far-end crosstalk. It is the latter with which the carrier systems are chiefly concerned, since similar types of systems on different pairs all transmit the same frequency range in the same direction. If, however, the lines concerned do not have smooth impedance characteristics, that is, a high degree of freedom from reflection effects, near-end crosstalk may be converted by reflection into far-end

crosstalk of sufficient magnitude to be controlling over the true far-end crosstalk.

This means that lines to be used for several type *J* systems must be made unusually smooth electrically—impedance variations kept within a few per cent. The achievement of such smoothness consists chiefly in:

1. Reducing the electromagnetic and electrostatic couplings to other pairs so that there are no large energy interactions, with corresponding impedance irregularities. Generally speaking, when the pairs concerned have been transposed for reduced far-end crosstalk up to the maximum frequency transmitted, this condition is also satisfied.

2. Minimizing the effect of intermediate and terminal cables. This latter problem has caused considerable concern and is responsible for the development of several new techniques in the design and treatment of such cables, where they appear in a long line otherwise consisting chiefly of open wire.

Cable Treatment

As a means of overcoming the reflection and attenuation effects of short pieces of terminal or intermediate cable, loading naturally suggests itself, as applied in type *C* systems, where the cable pairs involved are commonly equipped with carrier loading coils, spaced at about 700-foot intervals. This compares with the 3,000-foot or 6,000-foot spacings which are standard for voice-frequency loading. However, loading pairs in existing cables satisfactorily up to 140,000 cycles would mean coils at approximately 200-foot intervals. Because of physical limitations, existing manhole spacings, etc., this is highly impractical. A reasonable solution has, however, been found in the creation of a new form of low-capacitance high-frequency cable—a disk-insulated unit which has constructional features in common with the coaxial cables and a capacitance of only 0.025 microfarad per mile as compared with about 0.062 microfarad for conventional cable pairs. This permits more practical loading-coil spacings. These disk-insulated units are made up as spiral-fours, that is, two pairs (0.051 inch diameter wire) which form the diagonals of a square. When these cables are loaded with small coils at intervals of approximately 600 feet, they present impedance characteristics substantially equivalent to that of an open-wire pair over the desired frequency range. Accordingly, they form a desirable, although somewhat expensive, solution of the problem of intermediate or entrance cables. As shown in figure 6, the spiral-four units are bound together in complements of seven or less under a lead cable sheath similar to standard toll cables. It should be noted that the low-capacity disk-insulated loaded cables not only provide a satisfactory solution of the impedance matching problem, but they also give a cable circuit of low attenuation —approximately 1.2 decibels per mile at 140 kilocycles.

Nevertheless, where spare pairs exist in cables, it has often been found economical to use them for type *J* transmission. It is possible to use them only nonloaded, in which case the attenuation is very high —four to six decibels per mile, depending on the gauge, at 140 kilocycles, and impedance matching transformers are, of course, required at the junction of the open-wire and cable. There are cases where this higher attenuation may be permitted and these pairs are used by separating the type *J* range from the lower frequency range, which is transmitted through pairs equipped with the older type *C* carrier loading. The separation is accomplished by filters which are usually housed in small filter huts at the junction of the open-wire line and cable.

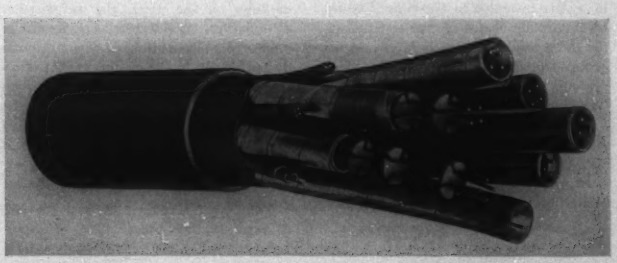


Figure 6. Disk-insulated cable

Sheath diameter 2.3 inches

In other cases it has been found economical to use the frequency-separation method with filters and to install new nonloaded cables of lower attenuation to lead in the type *J* frequency band alone. Paper-insulated ten-gauge pairs or the disk-insulated spiral-four cable of the type described above may be used for this purpose. In either case transformers are used to match the cable impedance to that of the open-wire line over the type *J* frequency range.

The reflection requirements are so severe and the effects of even short lengths of cable at the high frequencies so serious, that even short lead-in cables, where the open-wire line actually extends to the repeater or terminal building—cables which are only 100 or 200 feet long—must receive special treatment. This has also been accomplished by the use of the disk-insulated spiral-four cables, loaded.

Interaction Crosstalk

Because of the higher attenuation there will be many repeater points on a long line at which the type *J* system will be amplified but at which the other systems and wires on the line will pass through the station without amplification. In this case, even though the type *J* pairs are properly transposed to keep down crosstalk between themselves, there still remains the crosstalk between them and the other pairs on the line, not only pair-to-pair crosstalk but crosstalk from the type *J* pair to various circuit paths consisting of irregular wire combinations.

Two difficulties arise in this case: The first is that the crosstalk from the output of one *J* system into an irregular path may be retransferred into the input of a repeater on another type *J* system. The second is that the crosstalk from the irregular path may be returned to the input of the same repeater and either influence the over-all transmission characteristic or, if sufficiently severe, actually cause the repeater to sing. This general situation has made it necessary to introduce in the circuits at such points "crosstalk suppression" filters in the non-*J* pairs and longitudinal choke coils in all pairs.

Staggering

In addition to the various steps which are taken in order to reduce crosstalk by improving the line conditions, the type *J* system may include a feature which has been used in the type *C* system—the staggering of the channel bands used on

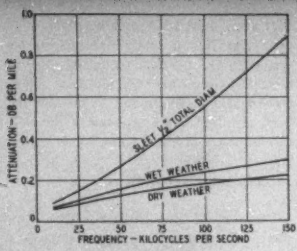


Figure 7. Attenuation-frequency characteristics of open-wire lines

neighboring pairs. The advantage of staggering results from the facts that (*a*) the sensitivity of the ear and the power of the voice vary over the audible range, (*b*) the efficiencies of transmitter and receiver also tend to vary over the frequency range, (*c*) part of a channel band may lie opposite "dead" frequency range on an adjacent pair, and (*d*) by controlling the arrangement of the sidebands the crosstalk may be made unintelligible even if not inaudible. The staggering feature is readily provided in the type *J* system by a suitable choice of carrier frequency for the second group modulator and first group demodulator. With the staggered systems the highest frequency used would be about 143 kilocycles.

Attenuation Problem

In what has preceded in the discussion of line problems, the emphasis has been confined chiefly to the question of the smoothness of a line from an impedance standpoint in order to keep down reflection effects and, correspondingly, to improve the operation from a system-to-system crosstalk standpoint. There is also the problem of the higher attenuation incident to the use of higher frequencies. Between 30,000 cycles and 140,000 cycles, the normal wet-weather attenuation for a 165-mil open-wire pair, for example, rises from about 0.13 to 0.28 decibel per mile—an increase of approximately 2:1. Repeaters on the type *J* system, if applied on the basis of approximately the same output level and minimum level requirements, must be spaced at about one-half the interval of the type *C* systems. Normal spacings for type *J* systems would therefore be expected to range from 75 to perhaps 100 miles where no large amount of intermediate cable existed.

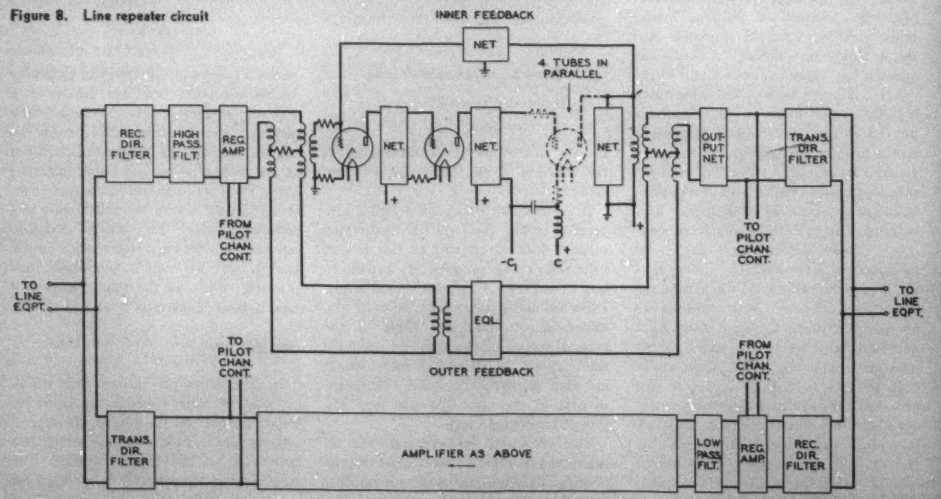
However, another problem, not present to a similar degree at the lower frequencies, tends in many cases to have a controlling effect on this spacing, that is, sleet or ice on the wires. With ice, frost, or snow on the wires, the wet-weather attenuation may be exceeded by very large amounts. The additional attenuation is due primarily to the coating on the wires themselves rather than the coating on the insulators. It arises from the potential gradient through the ice deposit in combination with the high dielectric loss characteristic of the ice or snow coating. Figure 7 gives examples of the attenuation frequency characteristics of open-wire lines, including certain measurements with ice coating. The exact increase in attenuation due to snow and ice naturally depends on the thickness and other characteristics of the coating. Even very thin coatings of ice on the wires tend to raise the attenuation at 140 kilocycles from the normal wet-weather figure of about 0.28 decibel to about 1 decibel a mile, that is, an increase of three or four to one. Extremes up to five decibels per mile have been measured for short lengths of line with ice nearly two inches in diameter. Such heavy ice obviously approaches the mechanical breakdown conditions for the line.

Where ice and sleet occur the repeater spacings may be reduced to about 50 miles or less. The repeaters now being provided for the type *J* systems have gains of approximately 45 decibels. Repeaters are under development which are expected to raise the maximum available gain to something like 75 decibels. The normal dry or wet weather operation of such repeaters would be limited to gains of perhaps 10 to 25 decibels depending upon the amounts of cable included. The problem of obtaining automatic gain control over the extra wide range required by the high sleet attenuations is a difficult one.

Repeaters

At each repeater point line filters and directional filters are required on both sides of the amplifying equipment to separate type *J* currents from those of

Figure 8. Line repeater circuit



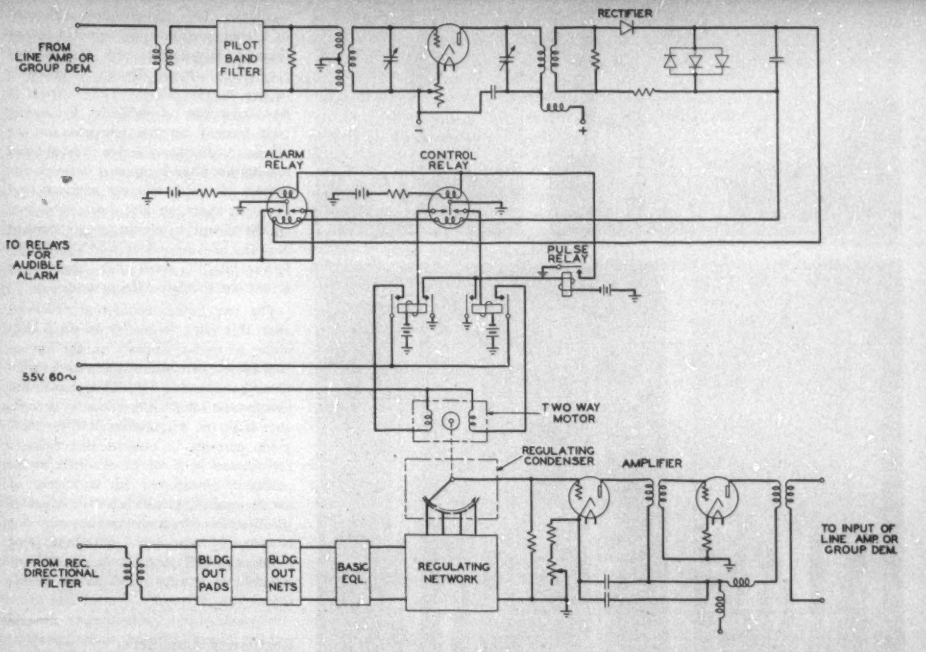


Figure 9. Regulating amplifier and pilot control

lower frequency services on the line and to separate oppositely directed groups for separate amplification in one-way line amplifiers. These filters have been described in connection with the terminals where they perform similar functions. Two regulating amplifiers, one for each direction of transmission, properly controlled to compensate for variations in the attenuation of the preceding line section, are also needed at each repeater point. These are described later under "Regulation."

Figure 8 shows the circuit of one of the line repeaters and indicates the location of the directional filters, and certain supplementary filters for suppressing frequencies outside the transmitted range; also the regulating amplifier circuit, and the pick-off of the pilot channel which controls the gain.

The line amplifier has three stages of pentodes. The first two stages use single tubes of high voltage amplification and low power capacity while the third stage has four power pentodes in parallel to increase the output capacity. Because of considerable heat developed by these power tubes, special precautions are necessary to dissipate the heat and to protect capacitors and other elements mounted near them.

Negative feedback to improve the operation of the amplifier is supplied over two paths. The inner feedback, from the plates of the output tubes over a properly designed network to the grid of the input tube, reduces the gain at frequencies outside the transmitted band and so prevents singing at those frequencies. It has little effect at frequencies within the type *J* range. The outer feedback path includes the input and output transformers, which are made as hybrid coils. In each of these one pair of the conjugate windings is connected to the incoming or outgoing circuit of the amplifier while the other pair is used for the feedback connection. By feeding back through the transformers in this way, they benefit by feedback in much the same way as the tubes, and the over-all characteristic of the amplifier is practically independent of the transformer characteristics. This feedback reduces the amplifier gain by over 40 decibels and correspondingly reduces modulation effects within the amplifier, and gives exceptionally stable transmission with respect to tube and voltage changes. It is also designed to improve and stabilize the input and output impedances.

Equalization

Equalization is necessary in each direction of transmission at a repeater point and in the receiving direction at a terminal, to compensate for frequency distortion produced by the preceding section of line. Fortunately, the attenuation-frequency curves for the usual open-wire circuits, that is, 104-, 128-, and 165-mil wire, have nearly the same shapes for section lengths giving the same attenuation at the maximum frequencies for the two directions of transmission, so that these various circuits can be equalized alike.

As is well known, the transmission frequency characteristic of an amplifier with large feedback is almost the inverse of that of the feedback circuit itself, so that the insertion in the feedback circuit of a network having the same characteristics as a line section will provide equalized transmission over the amplifier and section combined. In the outer feedback circuit of the line repeater is included an equalizer which has a characteristic sloping with respect to frequency in the same way as the variation

Figure 10. Typical installations

A—Auxiliary repeater station

B—Cable hut

C and *D*—Terminal installations

in loss under wet weather conditions of the longest open-wire section likely to be used. Thus, there is provided in the repeater a basic equalization for this longest wet-weather line. At a receiving terminal a basic equalizer is provided which performs this same compensation, but in this case the slope of the curve must necessarily be opposite to that of the line attenuation and of the equalizer in the feedback path of the line repeater.

Line sections, however, vary in length and in the amount of entrance cable included. In order that they may be properly corrected by this basic equalization, they must be built out to equal this longest wet-weather section. For this purpose there are provided flat loss pads and building-out networks whose losses have the same frequency shapes as the losses of short lengths of open-wire circuit. These pads and networks can be inserted or omitted by simple changes in strapping. They suffice to build out the shortest section which is expected to be used.

Pilot Currents

For a satisfactory system, arrangements must be provided to correct automatically for the effects on line attenuation due to changes in weather, by adjusting the amplification at each repeater point and in the receiving terminal circuit. To permit measuring these effects a pilot current of fixed frequency, near the middle of the transmitted band, and of constant amplitude, is supplied from each terminal. This is applied to the transmitting side of the terminal circuit between the 12-channel terminal and the first group modulator, where the message band lies between 60 and 108 kilocycles. The pilot frequency is 84.1 kilocycles which is obtained by modulation of 88 kilocycles, from one of the output taps of the channel supply of that frequency, with 3.9 kilocycles derived from a tuning fork oscillator. This modulation is performed in a copper-oxide bridge similar to the channel modulators and the desired product is selected by an 84-kilocycle carrier supply filter. The output of 84.1 kilocycles is sufficient to supply pilot current for ten terminals in the office. A sharply selective crystal band elimination filter is inserted between the output of the 12-channel terminal and the point where the pilot source is bridged on the circuit to eliminate any current near the pilot frequency which would interfere with the small pilot current that is sent out to control the system.

The two group modulation processes alter this pilot frequency of 84.1 kilocycles so that it appears on the line as 59.9 kilocycles in the west to east directional band, and as 116.1 kilocycles in the east to west band. Correction in accordance with the magnitudes of these mid-group currents in the two directions is satisfactory over all 12 channels under ordinary conditions. In the case of ice or snow the channels at the edges of the directional frequency groups may not be properly adjusted. Additional pilot frequencies will probably be needed ultimately to care for such unusual conditions.

Regulating Amplifier

Figure 9 shows the circuit of the regulating amplifier and above this, the circuit of the pilot-channel receiving equipment which controls it. Current enters the regulating amplifier circuit from the left, coming from the receiving directional filter through a shielded transformer and the pads and building-out networks used for equalization. At the terminals the circuit includes also the basic equalizer. Last in the circuit leading from the line to the regulating amplifier is the regulating network which consists of a series of three equal networks having a total loss of 20 decibels at 140 kilocycles in the east to west direction and 15 decibels at 84 kilocycles in the west to east direction. The network loss increases with frequency in the same way as the difference between dry and wet weather attenuation of the line. The two terminals of the regulating network and the two junction points between the three networks are brought to four sets of stator plates on an adjustable capacitor. The rotor of this capacitor, which has about the same area as one set of stator plates, is connected to the grid in the first stage of the regulating amplifier. Rotation of the capacitor therefore applies, to the grid of the first tube, a volt-

age which decreases continuously as the capacitor rotates from left to right.

The regulating amplifier has two stages of pentode tubes, a high input impedance necessary for the proper operation of the capacitor potentiometer, and feedback to stabilize the gain and to prevent intermodulation of the channels. Its output goes to the line amplifier at repeater stations, and to the first group demodulator at the terminals. At a west terminal there is interposed a high cut-off filter to eliminate frequencies above the upper band which may have been picked up on the open-wire line.

Pilot Control

The setting of the capacitor which controls the regulating network is determined in accordance with the amount of pilot current flowing in the circuit in the direction concerned. At repeater stations the pilot current is picked off at the output of the line amplifier, being separated from the message transmissions by a quartz filter which has about a 30-cycle pass band. For control of transmission from west to east at the repeater stations, this filter selects 59.9 kilocycles and for control of the oppositely directed transmission, 116.1 kilocycles. At the terminals the pilot-channel selecting filter is connected across the output of the auxiliary amplifier following the second group demodulator where the pilot frequency is 84.1 kilocycles. The pilot current from the pick-off filter is amplified in a single-stage amplifier which has feedback for constancy of operation and input and output circuits tuned to the pilot frequency. After amplification the pilot current is rectified by a temperature-compensated copper-oxide rectifier.

The resulting direct current passes through the operating windings of the control and alarm relays. These Weston Sensitrol relays are, in fact, microammeters with high and low contacts made by the pointers. The mechanical bias of the moving system is adjusted so that with the normal pilot current the pointer will remain free in the middle between the two contacts. A change of about 0.5 decibel in this current will cause the pointer of the control relay to make contact with the terminal at the corresponding end of its swing. As the limiting contacts are magnetized and the pointer is of magnetic material, good contact is insured. When contact is made on one side a 60-cycle circuit is closed through the motor which controls the regulating capacitor in such a direction as to cause the loss in the regulating network to be increased. Closure of the other contact similarly causes the loss in the regulating network to be decreased. Closure of either contact also closes a circuit containing a slow operate "pulse" relay to release the Sensitrol relays after an interval of about four seconds During this time the gain of the regulating amplifier will have been changed about 0.1 decibel. If now the pilot current level is within 0.5 decibel of normal the operation is complete. If not, it is repeated and the device keeps periodically testing the circuit so long as it is away from satisfactory compensation. There are also alarm circuits for attracting attention in cases of wide variations in equivalent. In severe ice conditions where a single regulating repeater has not sufficient gain to make up for the great loss in the line, the next succeeding repeater will do its utmost to make up the deficiency.

Conclusion

In what has preceded, developments have been described which are making it possible to provide a very substantial increase in circuits on open-wire pole lines without additional wire stringing. Illustrations of typical office installations of type *J* carrier equipment, unattended repeater stations, and filter huts are shown in figure 10.

Three stages in the development of the open-wire line over the past 20 years, giving successive increases in circuit capacity, are shown in figure 11. Prior to the application of carrier systems, a four-crossarm pole line would yield 30 voice circuits. Now, on a new line 256 circuits are potentially obtainable. Thus it is probable that the open-wire line will continue as an important factor in furnishing facilities in moderate numbers, particularly in the less densely populated sections of the country and where climatic conditions are not unfavorable. Installations of type *J* systems have already been made in various parts of the United States.

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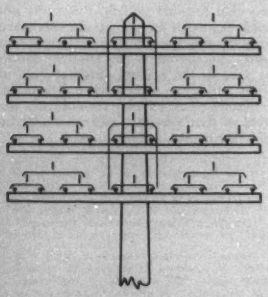
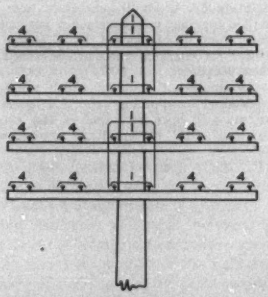
2. A New Three-Channel Carrier Telephone System, **J. T. O'Leary, E. C. Blessing, and J. W.**

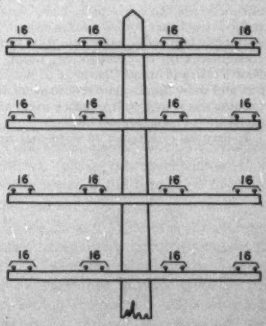


Facilities—30 voice circuits



Line construction with eight-inch-spaced non-phantomed nonpole pairs. Type C systems on all eight-inch-spaced pairs

Facilities—22 voice circuits, 48 carrier circuits, total 70



New line construction; all eight-inch-spaced pairs; no pole pairs; crossarms spaced 36 inches instead of 24 inches; no phantoms

Facilities—16 voice circuits, 240 carrier circuits, total 256

Figure 11. Growth in line carrying capacity

Beyer. *Bell System Technical Journal*, January 1939.

3. Transmitted Frequency Range for Circuits in Broad Band Systems, H. A. Affel. *Bell System Technical Journal*, October 1937.

4. A Carrier Telephone System for Toll Cables, C. W. Green and E. I. Green. *Bell System Technical Journal*, January 1938, and Electrical Engineering, May 1938.

5. Cable Carrier Telephone Terminals, R. W. Chesnut, L. M. Ilgenfritz, and A. Kenner. *Bell System Technical Journal*, January 1938, and Electrical Engineering, May 1938.

Discussion

James J. Pilliod (American Telephone and Telegraph Company, New York, N. Y.): The 12-channel open-wire carrier telephone systems came into commercial use in the plant of the long lines department of the American Telephone and Telegraph Company during the latter part of 1938 and in January of this year. Six such systems have been placed in operation, one in Texas between Dallas and Houston, two on the recently completed transcontinental route between Oklahoma City and Whitewater, one between Oklahoma City and Albuquerque, and two between Charlotte and West Palm Beach. These systems provide 72 channels, making a total of nearly 55,000 miles of telephone circuit.

The longest of these systems is the Oklahoma City–Whitewater (Los Angeles) whose route totals approximately 1,180 miles and in which there are 16 intermediate repeater points. The spacings of these repeaters were adjusted in accordance with knowledge of abnormal weather conditions. On the eastern end, between Oklahoma City and the Texas–New Mexico state line, in which sleet is to be expected, the average spacing is in the order of 50 miles, while west of this point where less severe conditions, from a transmission standpoint, are encountered, the spacing averages more in the order of 75 miles. On the southern systems spacings ranging from 75 to nearly 100 miles obtain.

Experience with these systems thus far has been very satisfactory. Excellent telephone circuits have been obtained and the channels, for the most part, have been extended by other types of facilities. For example, four-wire cable circuits out of Oklahoma City to Chicago, St. Louis, and New York, and out of Charlotte to Washington and New York, the combined facilities forming very long toll circuits over which excellent transmission is obtained.

It may be of interest to note that many of the channels between Charlotte and West Palm Beach are extended north to New York by means of the cable carrier systems between New York and Charlotte of the kind described in a paper by C. W. Green and E. I. Green, presented at the winter convention in January 1938, to form New York–West Palm Beach and New York–Miami circuits.

The use of this type of facility will doubtless be an increasing factor in our plans for circuit growth.

R. M. Goetchius (nonmember; American Telephone and Telegraph Company, New York, N. Y.): In addition to the systems mentioned by Mr. Pilliod, two additional type *J* systems were placed in service in 1938, one between Dallas and San Antonio, a distance of 280 miles, and one between Dallas and Longview, a distance of 130 miles. These two systems provided 5,000 miles of additional telephone circuit. In the application to existing telephone plant of all these type *J* carrier telephone systems, there are many engineering problems. For example, in laying out the intermediate repeater stations, consideration must be given to the probability of ice formations, static noise, which is a maximum in the summer, and possible interference from near-by radio stations. In many cases portable testing apparatus is used to make field measurements of the order of magnitude of these effects in the particular location.

After the number of auxiliary repeater stations between existing offices has been determined on these general considerations, it is necessary to make a detailed survey to determine suitable sites for the repeater office. Important elements in these considerations are the availability of commercial power and the accessibility to main roads. In most parts of the country commercial power is readily available within a few miles of the theoretically best location for a repeater station. However, in the case of several offices on the route between Oklahoma City and Whitewater, Calif., no source of power was available at the repeater site or even within a reasonable distance. Accordingly, windmill generators were installed together with emergency gas-engine generators which served as a source of power for charging the batteries used at these locations.

An important problem which must be considered in applying type *J* systems to an existing open-wire line is the extent to which the transposition system and configuration of the line needs to be modified to make it satisfactory for type *J* use. The solution in each case depends to a large extent on how well the line is transposed and on the number of type *J* systems for which it appears reasonable to arrange the line. On the present-day eight-inch-spaced well transposed lines, it is possible to apply a number of type *J* systems with relatively small changes in the present arrangements. On the older lines employing 12-inch spacing where only a limited number of crossarms are now available for type *C* carrier, the application of type *J* systems may require extensive retransposing and even respacing to six inches of the pairs which are used for type *J* operation. The solution for this problem which was worked out in Texas for the Dallas–Houston and Dallas–San Antonio systems was quite different from either of the general treatments mentioned previously. On both of these routes, which consisted of five full crossarms of wire, it was decided to provide additional facilities during 1937 before the type *J* system was available. In order to prepare the additional wire for future type *J* application and to eliminate the possible hazard due to wires from the upper crossarm falling on the type *J* wire, an additional crossarm was placed on both these lines 24 inches above the present top crossarm. This was accomplished by adding a simple extension fixture consisting of a four-inch steel H-beam arranged to be fastened to the pole by the through bolts supporting the two upper crossarms. On this additional crossarm there were placed four six-inch-spaced 128-mil conductors suitably transposed for type *J* operation.

While experience with commercial operation of the type *J* systems has been quite limited, the service results to date have been very good. The circuits themselves are very quiet and transmit a wider band of frequencies than previous types of open-wire carrier systems. The regulation features of the system automatically compensate for all normal weather changes and therefore minimize the amount of periodic maintenance work required to maintain satisfactory operation. As an example of this, during the first three months of operation of the Dallas–San Antonio system, there was not a single report of trouble to the testboard on any of the circuits operated over this system. Furthermore, if trouble conditions arise in the system, automatic alarm features notify the maintenance attendants and, in some cases, indicate the nature of the trouble so that remedial measures may be quickly initiated.

An Electronic Control Circuit for Resistance Welders

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FLEXIBLE electronic control circuits for the precise timing of resistance welders have been utilized thus far primarily on large welders. This paper describes a new circuit using recently developed types of cold-cathode electronic tubes which makes the application of such control economically practicable to small as well as large welders. The advantages of precise timing of welds by electronic means are well recognized, particularly for exact duplication of welds and for fabrication of materials difficult to weld or subject to physical or chemical changes if overheated. Utilization of the method on small laboratory or industrial welders may render expedient processes that heretofore were considered unavailable except for large-scale production.

Elements of Operation

In the circuit shown by the heavy lines near the top of figure 1, two band-ignitor mercury-arc tubes[1] are connected in a parallel-inverse relationship in series with the welder-transformer primary winding to conduct alternate half-cycles of current. These tubes consist of a mercury-pool cathode and a metal anode in an evacuated bulb with a metal band located outside the tube near the edge of the surface of the mercury. Conduction begins in such tubes upon application of a high-voltage from a spark coil to the external starting band if the anode is more than about 50 volts positive with respect to the cathode.* The function of the control unit, which constitutes the remainder of the circuit, is to initiate conduction in the band-ignitor tubes whenever the control switch S is moved from point 2 to point 1. Conduction is to begin precisely at a chosen phase angle in the supply-voltage alternation during an arbitrarily predetermined number of half cycles. The band-ignitor tubes then act as electrically controlled synchronously operating switches in series with the welder. Two are necessary to conduct the current in opposite directions because of their unilateral-conduction or rectifying characteristic. The threefold requirements of the control unit are that it (1) deliver a controllable number of high-voltage pulses to the starting bands of the band-ignitor tubes, (2) synchronize these pulses with the supply-voltage alternation at a controllable phase angle, and (3) provide operation which is independent of both the time at which the control switch S is operated and the interval it is held closed.

Operation in Detail

The Strobotron tube T_3 is the nucleus of the control circuit. Its function is to complete a discharge circuit for capacitor C_4 through the primary winding of the spark coil TR_2 and thereby to impress a high-voltage surge upon the starting bands of the band-ignitor tubes. Since the Strobotron tube is a relatively recent development, its characteristics as utilized in this application will be summarized briefly.

The electrodes of the Strobotron tube[2] consist of a cathode composed of a caesium compound, a metal anode, and two grids located between them. The tube is filled with neon gas at a pressure of about 1.5 millimeters of mercury. A glow discharge will start between the grids if the voltage between them reaches an amount of the order of 100 volts, with one grid positive and the other negative with respect to the cathode. If the anode is made 200 to 400 volts positive, the discharge will immediately transfer to the anode and cathode, and it will change from a glow into an arc with a low voltage drop if the source of supply for the anode-cathode circuit is capable of furnishing several amperes even momentarily. Less current to the grids is required for starting if the inner grid (the one nearer the cathode) is made negative and the outer grid (the one nearer the anode) is made positive than if the grids have the reversed polarities.

It is necessary that the high-voltage pulse to the starting bands occur twice during each cycle of the supply voltage in order that both band-ignitor tubes fire and conduct the alternate half cycles. To this end, the output of a peaking[3] transformer TR_1 is rectified by the full-wave rectifier tube T_1, and the resulting unidirectional peaked voltage wave, having a frequency of 120 cycles per second, is applied to a voltage divider consisting of R_4 and R_5 in series. The major portion of the peaked voltage, about 50 volts in amplitude, is supplied to the inner grid of the Strobotron tube through resistor R_6. The polarity of the voltage is such as to make the inner grid momentarily negative when the peaks occur. Capacitors C_2 and C_3 are included to furnish a surge of grid current and make the firing of the Strobotron tube more positive.[3] In addition they serve to prevent extraneous surges from starting the tube. The primary winding of the peaking transformer TR_1 is supplied through resistor R_2 and capacitor C_1, which form a resistance-capacitance phase-shift circuit for adjustment of the time in the cycle at which the peak of voltage from the secondary winding occurs. This voltage supply to the inner grid of the Strobotron tube is not sufficient alone to cause the tube to fire, but it insures that firing will occur at a frequency of 120 cycles per second when the remainder of the control circuit makes the outer grid positive by an amount greater than about 50 volts. Thus the second of the control-unit requirements listed above is accomplished.

The transformer TR_2 supplies power to heat the cathodes of the various high-vacuum tubes, and in conjunction with the full-wave rectifier tube T_4 it furnishes a direct voltage across capacitor C_7 to operate some of the tubes and to charge capacitor C_4.

Tubes T_4 and T_5 form a "trigger-controlled" time-delay circuit to supply the outer Strobotron grid with a direct voltage for a chosen time interval after the control switch is operated. The adjustable contact on resistor R_{13} is so set that normally grid number 1 of tube T_4 is negative beyond cutoff; hence, the current through R_{11} is negligible and the voltage of point E is practically that of D; namely, about 375 volts positive.

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The authors are indebted to H. E. Edgerton for many suggestions in the design of the circuit.

1. For all numbered references, see list at end of paper.

* Voltage polarities of tube electrodes are taken with respect to the cathode as a reference in this article unless otherwise stated.

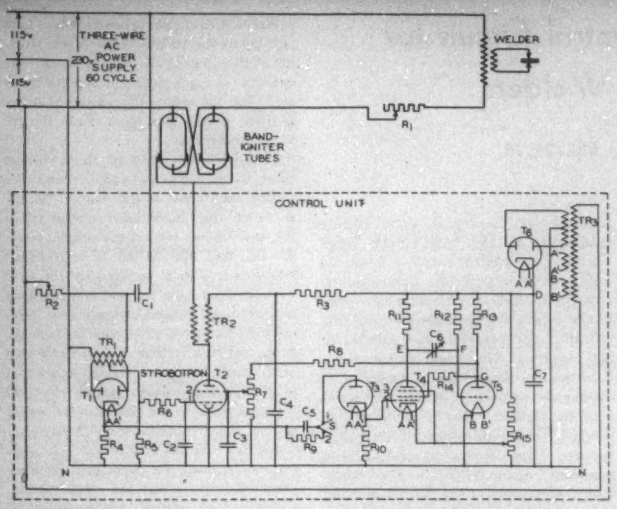

Figure 1. Electronic control circuit for a resistance welder

The control unit is enclosed by dotted lines

Circuit constants:

R_1 —	10 ohms	T_3 —	Type 01A
R_2 —	5,000 ohms	T_5 —	Type 6X5
R_3 —	3,000 ohms	TR_1 —	Peaking transformer
R_4 —	100,000 ohms		
R_5 —	1,000,000 ohms	TR_2 —	Automobile-type spark coil
R_6 —	25,000 ohms		
R_7 —	1,000,000 ohms	TR_3 —	Plate and filament supply transformer (Thordarson number T7020)
R_8 —	1,000,000 ohms		
R_9 —	200 ohms		
R_{10} —	100,000 ohms	C_1 —	1.0 microfarad
R_{11} —	100,000 ohms	C_2 —	0.001 microfarad
R_{12} —	1,000,000 ohms	C_3 —	0.005 microfarad
R_{13} —	100,000 ohms	C_4 —	1.0 microfarad
R_{14} —	50,000 ohms	C_5 —	0.005 microfarad
R_{15} —	25,000 ohms	C_6 —	Decade capacitor
T_1 —	Type 6H6	C_7 —	24 microfarad
T_2 —	Strobotron		
T_3 —	Type 1V		
T_4 —	Type 77		

The grid of tube T_3 is held at a positive voltage through resistor R_{13}; therefore this tube conducts a relatively large plate current, the voltage drop in the plate resistor R_{13} is large, and point G is normally only a few volts positive. The current to the grid of the tube T_3 causes a large voltage drop in R_{12}, making the voltage of point F also only a few volts positive, with the result that capacitor C_6 is charged to about 350 volts, terminal E being positive with respect to terminal F.

When a positive voltage impulse is impressed on grid number 1 of tube T_4, in a manner to be described later, the plate current through resistor R_{11} suddenly rises, the voltage of E falls, and, because the charge on the capacitor C_6 cannot change instantaneously, the grid of tube T_3, point F, is suddenly made highly negative as is indicated in the idealized wave forms of figure 2. The plate current of tube T_3 therefore decreases suddenly. As it decreases, thereby increasing the screen-grid voltage of tube T_4, which increases the plate current in T_4 and accelerates the changes. The result is that grid number 2 of the Strobotron tube is suddenly made positive, and it remains fixed at this positive voltage until the transient described below is completed.

When point F is driven negative, a charging current flows from D through R_{12}, C_6, and T_4 to N. The voltage of the grid of T_3 therefore approaches that of D in a manner that can be represented approximately by an expression involving an exponential with a negative exponent. The grid voltage becomes equal to that of the cathode of tube T_3 in a time of about $0.69\ R_{12}C_6$ seconds, where R is in ohms and C is in farads. After the elapse of this time, tube T_3 begins to conduct again, and the voltage of the screen grid of tube T_4 is thereby decreased. This causes a decrease of the plate current and an increase in the positive voltage of point E, which in turn increases the voltage of point F and accelerates the return of the circuit to its initial condition. The outer grid number 2 of the Strobotron tube T_2 is thus suddenly brought back to a low positive voltage after a time dependent upon the size of capacitor C_6.

The operation of the time-delay circuit described here results in the application of a positive voltage to grid number 2 of the Strobotron tube for a controlled time interval whenever an impulse is delivered to grid number 1 of tube T_4. During this interval the Strobotron will fire at 120-cycles-per-second frequency in accordance with the voltage supplied to its grid number 1, and pulses synchronized with the supply-voltage alternations will be delivered to the starting bands of the band-ignitor tubes.

The first control-unit requirement listed here, namely, that the unit deliver a controllable number of high-voltage pulses to the starting bands of the band-ignitor tubes, is only partially fulfilled by the circuit thus far described. If a control switch were incorporated in the circuit merely to connect grid number 1 of tube T_4 to a source of positive voltage upon manual closure, the number of half cycles of welding current conducted during the controlled time interval would depend upon the time in the cycle at which the control switch was closed, and the welding current would continue as long as the switch was held closed.

These difficulties are avoided by interposing tube T_3 with its associated circuit to deliver only one short impulse to grid number 1 of tube T_4 regardless of the length of time the control switch S is held closed; and to cause this impulse to occur at a particular point in the supply-voltage cycle regardless of when the control switch is closed. Control switch S (actually a relay for remote control) is normally closed on position 2, and operation transfers it to position 1. A small portion (about ten volts) of the next succeeding rectified peak of voltage from transformer TR_1 then appears across resistor R_4 and charges capacitor C_5 through tube T_3 and resistor R_{10}. A small voltage pulse caused by the charging current through R_{10} is delivered to tube T_4 and the controlled weld is thereby initiated. Capacitor C_5 cannot discharge while the control switch is held closed on position 1 because of the rectifier tube T_3. Hence, only one pulse is transmitted to tube T_4 each time the switch is operated, and a number of half cycles of welding current predetermined by the setting of capacitor C_6 occurs.

Controls and Adjustments

The external adjustments on the panel of the control unit, illustrated in figure 3, are the half-cycle adjustment, C_6, which is a decade capacitor, and the conduction-angle control R_2 for adjustment of the starting point of conduction within the half cycles. The decade capacitor provides for any number of half cycles from one to ten, and the range may be extended to much larger numbers of half cycles by the addition of an external supplementary capacitor in parallel with C_6. The conduction-angle control permits delay of the point of ignition of the band-ignitor tubes in each half-cycle of supply voltage beyond the natural lagging phase angle of the welding-load current. This delay makes possible the elimination of a high transient surge of magnetizing current,[4] and a reduction in crest current.[5] It insures exact duplication of successive welds and gives smooth, continuous control of the welding heat. In all, four methods of controlling the welding heat are provided, namely, by adjustment of (1) the number of half cycles, (2) the firing point within the half cycles, (3) the resistor R_1 in series with the welder-transformer primary winding (practicable only with small welders), and (4) the taps on the welder-transformer windings.

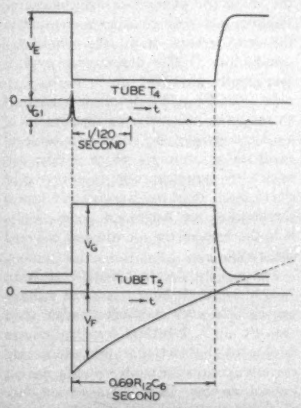

Figure 2. Approximate wave forms of the voltages in the time-delay circuit

Voltages are for the lettered points in the circuit, and are measured from the cathode of the corresponding tube

Two internal adjustments are included in the control unit to provide for differences in replacement tubes. These are the voltage adjustment R_7 for the grid number 2 of the Strobotron tube, and the grid-bias adjustment R_{15} for the tube T_4. The adjustable contact on R_{15} is set by advancing it upward on the diagram slightly beyond the point at which the time-delay circuit becomes stable and ceases to oscillate continuously with the control switch S in its normal position number 2. The setting of the adjustable contact on resistor R_7 is made by advancing it upward on the diagram slightly beyond the point at which the Strobotron first fires when the control switch is moved to position number 1. Once made, these adjustments should not have to be changed.

Performance

A desirable feature of the resistance-welder control circuit is that the main tubes in it are of the cold-cathode type and do not require heating power. As a result, the Strobotron and the band-ignitor tubes are ready for service instantly without the time-delay requirement for cathode heating necessary with some control tubes. The only time delay in starting the unit is that inherent in the cathodes of the other tubes, which are of the radio-receiver type and require a time comparable to that of the ordinary radio receiver for heating. When the main switch is closed to excite the whole circuit, the cathode of the triode T_8 in the time-delay circuit must reach its thermionic emitting temperature before that of the rectifier tube T_6; otherwise grid number 2 of the Strobotron tube will receive a positive voltage, and welding-current cycles will continue steadily for a few seconds. For this reason a quick-heating filament-type tube, the 01A, is included in the circuit.

The calibration of the decade capacitor C_6 is practically independent of manufacturing variations in tubes T_4 and T_5 because the resistors R_{11}, R_{12}, R_{13}, and R_{14} are large compared with the effective resistances of the tubes while they are conducting. Thus it is not necessary to recalibrate the capacitor when tubes are changed.

The life of the Strobotron and the band-ignitor tubes depends primarily on the number of welds made, and is independent of the standby intervals between welds during which the unit is left connected to the power supply. These cold-cathode tubes are of simple and rugged construction, and laboratory tests indicate their life to be adequate to render them practical for spot-weld service.

The control unit may be assembled in a small cabinet no larger than a table-model radiobroadcast receiver, for all the tubes and circuits in it are of low power ratings. The unit is sufficiently powerful to control the band-ignitor tubes for a welder of any size. It is also suitable for the control of ignitron-type tubes if the spark coil TR_3 is replaced by an appropriate transformer. The model illustrated in figure 3 has been used thus far to operate a small welder of one-kilovolt-ampere rating with current crests of 300

Figure 3. External and internal views of the resistance-welder control-unit assembly

amperes, but there appears to be no inherent limitation to its use with larger welders if band-ignitor tubes of sufficiently high ratings are substituted in the circuit.

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1. **T. S. Gray** and **W. B. Nottingham**, *Review of Scientific Instruments*, volume 8, February 1937, pages 65–8.

2. **A. B. White, W. B. Nottingham, H. E. Edgerton,** and **K. J. Germeshausen**, *Electronics*, volume 10, March 1937, pages 18–21.

3. **O. Kiltie**, ELECTRICAL ENGINEERING, volume 51, November 1932, page 802.

4. **R. N. Stoddard**, ELECTRICAL ENGINEERING, volume 53, October 1934, page 1366.

5. **J. W. Dawson**, ELECTRICAL ENGINEERING, volume 55, December 1936, page 1374.

Discussion

L. G. Levoy (General Electric Co., Schenectady, N. Y.): The authors have presented an interesting description of a control circuit for spot-welding applications. I would like to ask what actual crest voltages are required on the ignitor bands of the power tubes? High voltages, even though of the nature of an impulse of short duration, are frequently a barrier to widespread application, particularly when the same result can be accomplished without the use of high voltage.

The circuit proposed in figure 1 is synchronous starting with respect to phase angle, but is random starting with respect to polarity of the first half cycle of any spot. In a simple spot welder there are no cumulative residual current transients, since the electrodes are lifted from the work after the termination of each spot. There is, however, some residual flux left in the core of the welding transformer. If the spot length and polarity of starting are properly controlled, the effect of this residual flux can be minimized. In a welding transformer liberally designed for the voltage applied, the effects of residual flux are small, but in many cases welding transformers normally run at high flux densities, in which case the effect of residual magnetism may give rise to primary transients and also may result in greater magnetic energy storage at the termination of the spot. This often gives rise to undesirable arcing at the electrodes when they are quickly removed from the work after the cessation of primary current, tending to shorten the electrode life and also cause pitting of the surface of the work. For these reasons, where precise work is to be done it would be desirable to incorporate the feature of unipolar starting in the control circuit. To get the maximum benefit of this, the spot length should be adjustable in full cycle increments only. These features are available on existing electronic controls. Where odd half-cycle spot lengths are required, antipolar starting is provided for in available electronic controls. For interrupted spot or seam welding, proper control of the starting polarity and spot length is a requisite to consistent welding.

T. S. Gray: The actual crest voltage required on the ignitor bands of the power tubes, about which Mr. Levoy asks, depends on the thickness of the glass through which the voltage acts. In glass tubes made with ordinary borosilicate glass approximately $1^1/_2$ millimeters thick, the crest voltage required is about ten kilovolts. Thinner glass between the metal ignitor and the mercury pool makes possible a reduction of this crest voltage by a factor of three to five (see K. J. Germeshausen, *Physical Review*, volume 55, Jan. 15, 1939, page 228). There is no serious problem of high-voltage wiring or protection associated with the use of the band-ignitor tubes, because the problem is similar to that in an automobile and the spark coil may be located nearby in the same metal enclosure with them.

The suggestion by Mr. Levoy that for a minimum magnetizing transient the timing should be adjusted in multiples of a full cycle is important, and this adjustment would ordinarily be made except when a single half cycle is desired. It is interesting that provision for unipolar or antipolar starting becomes important with large welders and with interrupted spot or seam welding. In our work with small spot welders we have not observed arcing of the electrodes or pitting of the surface of the work as a result of the lack of such control.

The A-C Arc Progresses

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MEMBER AIEE

ELECTRIC WELDING could be pictured very accurately to an electrical engineer as an attempt at maintenance and control of a short circuit. In resistance welding, whether spot, butt, roller seam, flash, or projection, it is an actual short circuit with definite resistance and low voltage drop. The arc is the maintenance of a short circuit in a very unstable medium, generally air, with a comparatively high voltage and nature conspiring to extinguish it. The "holding" of a metal arc is especially difficult as one electrode is continuously melting away into the other electrode called the "work."

In 1930 the AIEE published an article by the writer on time recovery and control of the welding current and voltage, as shown by an oscillograph, with both direct and alternating current. Direct current holds an arc very readily and for the single carbon arc it is so far unchallenged. Alternating current, however, is used for the double carbon arc and for hydrogen-flame double or single tungsten shielded arc welding. It was considered impossible to hold an a-c metallic arc continuously previous to the writer's efforts. The a-c arc, however, once established, is much easier to control and nonferrous alloy welding, even with copper-base alloys, is being accomplished by the use of capacitance and the high-frequency pilot circuit. The introduction of desirable gases, instead of air with its oxygen and nitrogen, to help hold the arc by means of covering on the rods or by surrounding the arc as in "atomic" or "shielded arc" welding, is a very great improvement in the arc stream from the "holding" standpoint. The deposited metal is also greatly improved.

In 1920 the AIEE JOURNAL contained an article by the writer on phenomena of a-c arc welding, also showing a table of electrode arc voltages which is now up-to-date by the general adoption of covered electrodes. If there were ever natural companions for combined good results it is the firm of the a-c arc and covered electrodes.

The a-c arc does not wander or have "arc blow" and the current and voltage can be held ever so much steadier than the d-c arc. Whether for this reason or due to the fact that the alternating current agitates the molten puddle during crystal growth, it is an accepted fact that alternating current and covered electrodes make the highest quality weld deposit.

Class I pressure vessels are welded with alternating current. The $11,000,000 Boulder Dam job was welded with alternating current.

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Copper alloys—Monel, bronzes, etc.—still give trouble with the metallic a-c arc although the double carbon arc is better for brazing with alternating current than with direct current. Capacitor circuits have brought copper, bronze, and brass alloy welding into the scope of the a-c metallic arc. Previously the d-c carbon arc was the solution for copper-alloy welding and brazing not done by gas welding. The "atomic" or hydrogen-bathed arc has opened a new field for alternating current in that special jobs requiring no contact with the air are extending the field of the art. Copper welding, Monel, stainless, and "tricky" alloys are handled with ease by the hydrogen-flame arc.

The superimposed high-frequency circuit is a very desirable adjunct for special welding purposes. With an air-core transformer and capacitor oscillating circuit (figure 1) high frequency, as used in vaudeville shows, is here made to jump the gap and break down the surfaces for the following of the arc current. This is especially desirable for thin work, stainless, mill-scale plates, and tack welding. It is also useful in starting and maintaining the hydrogen "atomic" arc and in maintaining any arc under specially disadvantageous circumstances such as oil, wind blowing, grease, water, etc. This high frequency can either be superimposed on a-c or d-c arc circuits but is generally used with low-current a-c circuits.

The writer has preached the advantages of covered rods and a-c welding for 26 years. The opposition to covered electrodes and alternating current was tremendous. Even though the AIEE published the writer's 1920 article, the major companies fought acceptance of the truth of the qualities shown very strongly. In fact, acceptance of alternating current only recently has become universal in the United States although in Europe this progress had preceded ours. However, in this country for several years all important work such as class I pressure vessels and oil-fired vessels, penstocks, and those companies who have a testing laboratory use a-c welding for its quality product. In addition to its quality, alternating current is faster and, hence, cheaper in labor, which is 80 per cent of the cost of arc welding. The first cost and the electrical cost of operation is less with alternating current and there is no maintenance. There is no electrolytic action or positive or negative corrosive forces. The deposit is neutral, of finer grain structure, free from porosity, and generally better on all iron and steel work.

Why has a-c arc welding progress been so retarded? The chief sales disadvantage against alternating current has been the open-circuit voltage, which lowers the power factor and is liable to cause nervous shocks especially in wet places.

The writer has lately developed a unique method of lowering the voltage by an odd circuit as shown in figure 2. In its simplest form it consists of a leakage transformer with two windings. One winding is across the operating voltage, say 80 volts, and the other winding is in series with the operating voltage, open-circuited until contact is made. On open circuit the second winding subtracts from the first one leaving the voltage low, say 40 volts. During welding the second winding becomes a reactance, lowering the voltage to the arc voltage of 40. There is no doubt but that this action occurs through phase shifting, exactly as described in the 1920

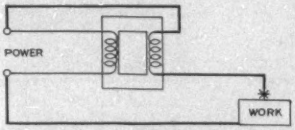


Figure 2. Basic buck-back circuit

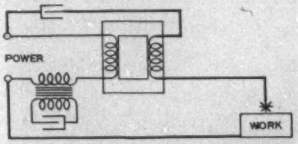


Figure 3. Compensated buck-back circuit

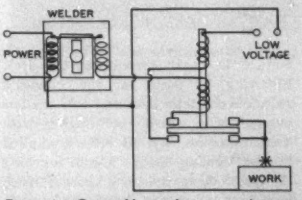


Figure 4. Original low-voltage control circuit

article. In that case, however, the voltages were added. In this case the second winding is used to subtract on open circuit by plain transformer action and under load to subtract by voltage reactance drop and phase shift. Capacitance can be used in this circuit to raise the bucking voltage which disappears under load. Professor Comfort A. Adams and the writer have had a good many months of argumentation as to the interaction of these two circuits and at various current and turn values the action is widely different. The writer admits he cannot explain everything that goes on in this circuit. Perhaps some professor and student will take this up as a thesis. Whether explained or not, it operates as described, and is especially applicable for heavy welding. Figure 3 shows a modified form of this circuit.

The writer has also developed a method of holding the open-circuit voltage low while enjoying the steadiness of applied higher voltage (although this higher

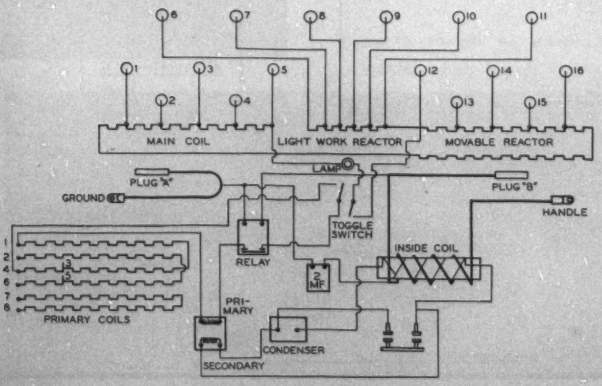


Figure 1. Superimposed high-frequency circuit

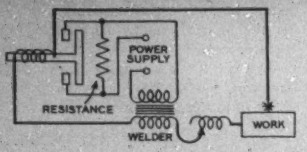


Figure 5. Primary voltage cutdown control

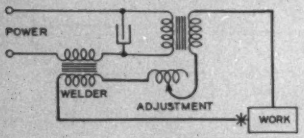


Figure 6. Primary counterbalanced

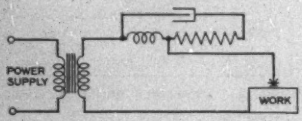


Figure 7. Hunter series circuit

voltage is never present at the arc). Referring to figure 4, the magnetic switch is normally open and only the low voltage of a small (bell-ringing size) transformer at, say, 40 volts is applied to the welding leads. Upon touching the electrode to the work the difference in reactance between the work electrode circuit and the transformer parallel circuit causes the magnetic switch to close the arc circuit, opening the "bringing in" circuit and the switch is held in by a series winding until the arc exceeds, say, 40 volts when it drops out. This system is "positive safe" and thousands are in use, some with the doubtful improvement of a time delay in dropping out. The device is used on large welding transformers in the primary circuit thus cutting off even the core-loss expense and for small arc welders the 40 volts can be obtained from the welder itself by a tap or separate winding.

Another method of accomplishing low voltage, figure 5, also developed by the writer, is to put a resistance or reactance or capacitance in the primary of the arc welding transformer and by a simple series relay cut out this voltage-lowering impediment during welding.

Still another method, figure 6, is to counterbalance a reactance or capacitance in the primary circuit by the welding current but this is limited to a very short range of welding current with insufficient range of adjustment.

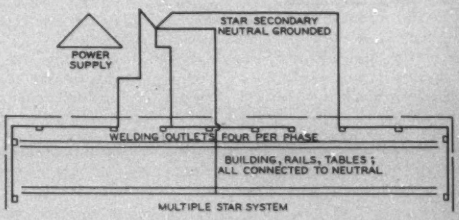
The power factor of a-c arc welding can be overcome with capacitors, which capacitors also give spontaneity of arc, this action being similar to that of condenser coils in an automobile ignition circuit or as in an oil-boiler ignition transformer. Capacitors can also be used to lower the open-circuit voltage by neutralizing the inductive action, as in the Hunter circuit (T. M. Hunter, president of the American Transformer Company), figure 7. Of course, anywhere a capacitor is in the circuit it has a correcting effect and if enough capacity is used the power factor can be leading. F. C. Owens of Fayetteville, N. C., also helps power factor and the welding arc by use of capacitors in multiple, and wherever a capacitor is placed in or across all or part of an arcing circuit, it helps the arc and, of course, the power factor. Balancing of capacitance in the primary of the 40-40 circuit is also feasible but capacitors are only as reliable as storage batteries.

Another disadvantage of a-c welding, from an operating standpoint, is the fact that it operates single phase and very often not on a line built for single phase and the voltage droops and the welding withers accordingly.

With the multiple star system, as schematic wiring diagram and photographs show, there is an adequate tank or reservoir in the shape of the mother transformer absolutely to preclude any drooping. With the a-c multiple system the efficiency is three times better than with a multiple d-c system and twice as good as that of any single-motor-generator system. The independent control of both amperage and voltage at each station also removes one of the disadvantages of d-c multiple system where only one voltage is available for the entire system. D-c multiple installations would be used more if their efficiency were not so poor.

A typical welding-shop floor plan is shown in figure 8, with mother transformer *A* star connected, neutral grounded to building steel, rails, work tables, etc., and one cable to each general location to outlet transformers along the wall, overhead, or generally out of the way. The operator has but one welding lead. D-c motor generator sets have two welding leads, three power

Figure 8. Multiple star system


STAR SECONDARY NEUTRAL GROUNDED
POWER SUPPLY
WELDING OUTLETS FOUR PER PHASE
BUILDING, RAILS, TABLES; ALL CONNECTED TO NEUTRAL
MULTIPLE STAR SYSTEM

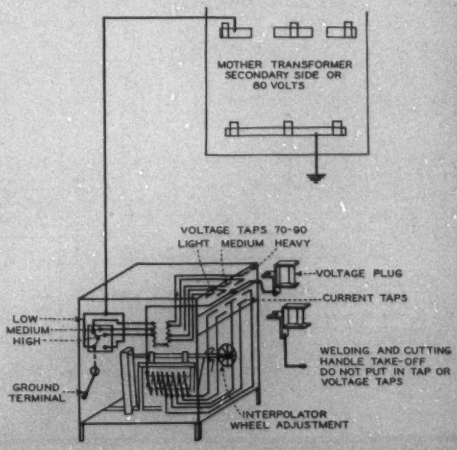


Figure 9. Detail, mother transformer and station

leads, and a motor generator for each arc.

Still another great advantage of the multiple star system is the space in the shop is not interfered with welding apparatus, nothing but outlets on the wall being necessary for this system.

The 220-, 440-, 550-volt power lead wires to the alleged portable single-operator machines are done away with and a very great hazard of fire and safety is obviated.

The second greatest detriment to single-operator transformer operation is interference which is a by-product of electrical line drop. The mother transformer reservoir system precludes this and I^2R is a negligible component where reactance control is used. In single-operator installations, part of each unit is tied up if the full capacity is not used.

D-c multiple systems are popular where one single voltage and no polarity reversing will do but the resistance method of control of d-c installations makes them very costly to operate and the large motor and its losses makes fractional operation very uneconomical. This is obviated in the multiple star system (figure 9). In single-operator installations there can be no diversity factor of the equipment. In the multiple arrangement the entire output can be had or any fraction of it with the maximum diversity factor and efficiency and no stand-by losses.

The a-c arc is one-fourth of the cost of a multiple d-c system and one-half that of any d-c motor generator set.

Where the work is heavy enough to stand the reservoir capacity, chipping and caulking are not necessary, and up to $1^1/_2$-inch-thick plates, this system has accomplished this desirable step forward with the testing and consent of the interested authorities, both the insurance, The American Society of Mechanical Engineers and the National Inspection Bureau. This is a saving of 50 per cent alone and alternating current is faster than direct current generally.

This multiple ring system (figure 10) is a planned installation. The country's welding progress has arrived at a point where this Topsy-like method of growing by adding single-operator machines should be superceded by an orderly designed welding power plant. In this connection, this system fits in beautifully with electric power, steam, or Diesel installations, or combinations of either. This multiple star system, which provides great chunks of power where needed without affecting the light and medium work outlets, is also ideal for the submerged-arc heavy welding or any requirement where combined amperage is necessary.

Figure 10. Multiple star system

Hamler boiler, Chicago

Figure 11. Public Service preheating welding

The latest development of induction hysteresis stress-relieving operates perfectly with this system. An illustration of two pipe joints preheated, welded, and normalized with the Smith-Dolan a-c preheating development is shown in figure 11. There were 8,900 such welds at the Essex plant of the Public Service Electric and Gas Company accomplished perfectly with their 60-cycle power. The test pressure on these joints was 2,250 pounds; the operating temperature was 950 degrees Fahrenheit. There were no leaks or failures of any kind. The metal was that tricky alloy to weld, carbon molybdenum steel.

The d-c arc is better for overhead and some vertical welding. The general use of covered electrodes has reduced this advantage of direct current materially and most industrial work is now "positioned."

Alternating current has become the steam shovel of welding, leaving direct current for the special work tentatively.

Discussion

A. U. Welch (General Electric Company, Pittsfield, Mass.): As pointed out in this paper, a-c arc welding has made great strides recently, largely due to the fine performance obtained from modern covered electrodes. The remarkable improvement

in arc stability obtained from these newer covered electrodes has almost eliminated the necessity for complicated welding circuits and equipment, and excellent results are being obtained with simple adjustable reactance control of arc current.

The circuit shown in figure 2 is merely a regulating autotransformer with its series winding connected bucking. It gives exactly the same performance as any other reactance-controlled transformer with the same open-circuit voltage and current. The circuits shown in figures 3, 6, and 7 use capacitance in series with inductive reactance to improve arc stability or to permit lowering open-circuit voltage somewhat with the same arc stability. The circuit operates in such manner that if an arc should fail to restrike after passing through normal current zero, the voltage across the reactor, or the equivalent reactance of the transformer, collapses immediately, leaving a charge on the capacitor. The voltage available to restrike the arc is then the sum of the capacitor and transformer open-circuit voltage, which will be higher than the normal open-circuit voltage. The capacitor soon discharges through its transformer, autotransformer, or discharge coil, and the circuit returns to normal open-circuit voltage. Since this is a series resonant circuit, extreme care must be taken in applying it to arc welding in order to avoid dangerous overvoltages on the capacitors, reactors, and transformers. Operation would not be so precarious if no adjustment of current output were required.

In order to obtain improved arc stability, it is necessary that the capacitive reactance partly compensate for the inductive reactance, or vice versa. In order to control current, either the inductive or capacitive reactance must be varied, and if the range of current is at all wide, the two reactances are likely to become so nearly equal as to form a completely resonant circuit with very high voltages on both capacitor and reactor. Furthermore, any additional reactance inserted in the circuit, which may be inherent reactance in the primary and secondary leads, will greatly disturb the operation of the circuit, change the current output to a very marked extent, and in some cases throw the circuit into resonance. Even the normal starting transient currents of the reactor and capacitor are apt to change the inductance sufficiently to cause resonance troubles.

A connection of capacitors in shunt across the primary leads of an arc welding transformer improves power factor, but has no effect on the welding arc except possibly to help hold the primary voltage up to its rated value.

The "multiple star system," which is merely a system of distributing power at low voltage instead of primary voltage, in general offers no advantage over distributing at usual primary voltages, such as 220, 440, or 550 volts. The price of adjustable reactors for the multiple star system is essentially the same as the price of arc welding transformers designed to run off primary voltage, and the elaborate system of heavy cables required for distributing at low voltage is much more expensive than the usual primary wiring in conduit. This is particularly true if isolating switches are used at each welding station, as is the usual practice, to prevent one faulty unit from shutting down the entire system. The cost of switches for the low-voltage high-current system is very much more than for the primary circuit switches.

The adjustable-reactance welding transformer which is the accepted standard equipment for a-c arc welding has the advantages over the circuits presented in this paper of simplicity, low cost, low maintenance, adaptability, and freedom from overvoltages and other dangerous phenomena.

R. F. Wyer (General Electric Company, Schenectady, N. Y.): As always, Mr. Holslag's paper stimulates a great deal of thought, as he doubtless intended it to do. One idea that seems to me needs further clarification is the use of a three-phase mother transformer and individual welding stations to counteract voltage droop in power circuits that lack stiffness. If a power line into a welding shop is too light to handle the additional load imposed by a-c welding, then the only means for enabling it to carry this load without additional voltage droop is the installation of capacitors, synchronous motors, or synchronous condensers to give a leading-power-factor load sufficient to bring the power factor of the whole plant load up to the point where the total kilovolt-ampere input will not exceed the kilovolt-ampere input previously existing in the plant. That is to say, sufficient leading reactive kilovolt-amperes must be furnished in the form of capacitors or synchronous machines to cancel the lagging reactive kilovolt-amperes of the welding load, and in addition some of the lagging reactive kilovolt-amperes of the other plant load. Only by this means could the total kilovolt-ampere load of the plant, and thus the voltage regulation of the power line be held constant in spite of the addition of the welding load.

The reference to the mother transformer as a tank or reservoir to preclude voltage droop is not clear to me. It might be thought that a three-phase transformer would distribute a single-phase load over all three phases of a three-phase power circuit. This, however, is not true, since a single-phase load on the secondary of a three-phase transformer will result in single-phase power input to the transformer, and the unbalancing effect on the power supply will be just the same as if only a single-phase transformer were used. It is true that if all three phases of the mother transformer are loaded on the secondary side, then the welding load will be distributed on the power line. However the same thing can be accomplished by simply distributing ordinary welding transformers on the three phases of the power circuit, and the load distribution will be accomplished.

It is difficult to see how there could be any economy in distributing welding power at low voltage, such as 80 volts, around a welding shop. This practice is quite the opposite of the trend in power distribution, where the tendency is to go to higher voltages in order to save copper.

Returning to the voltage droop consideration, it would seem that extraordinary precautions would have to be taken to avoid even increasing the voltage droop through the use of low-voltage power distribution to the various welding stations on account of the reactive drop in voltage which is inherent in all a-c distribution circuits. This is directly proportional to current, and since the current carried by the distribution circuit must necessarily be increased when using low-voltage distribution, I would expect that the trouble due to voltage droop would be accentuated rather than counteracted.

To use specific figures, suppose three welders are each using 250 amperes at various locations in a shop. With the ordinary single-operator transformer welder set-up, individual 440- or 220-volt leads, one pair from each phase, would be run to the individual transformers. Assuming 440-volt distribution, the current in these leads would be about 46 amperes. The actual primary current would depend on the open-circuit voltage on the secondary of the welding transformer, but 46 amperes is figured on the basis of an 80-volt open-circuit voltage, by multiplying the welding current by the ratio of transformation of 80/440.

With an 80-volt distribution system, and assuming that 80 volts open-circuit voltage is desired by the operator, then the current in the distribution circuit between the mother transformer and the individual welding stations will be 250 amperes, because there is no ratio of transformation in the individual welding station. Of course, if the open circuit voltage at the welding station were reduced to 60 volts, then the current in the 80-volt distribution circuit would be somewhat less; it would be $6/8 \times 250$, or about 190 amperes.

Remembering that the loss due to I^2R in the distribution lines is proportional to the square of the current in those lines, with a ratio of 46 to 200 amperes, the ratio of the weights of copper which will be required to give the same loss in the two systems will be 30 to 1.

In view of the foregoing considerations, it appears to me that a low-voltage distribution system such as is proposed by Mr. Holslag would result in an increase in interference between operators due to voltage drop in the supply lines to the individual welding stations, instead of a decrease as suggested in the paper.

K. L. Hansen (Harnischfeger Corporation, Milwaukee, Wis.): The paper is replete with assertions which no doubt will be accepted for what they are worth. For example, it is stated that the efficiency of the a-c multiple system is twice as high as that of any single-motor-generator system. As the efficiency of some motor generator sets is above 50 per cent, the efficiency of the a-c multiple system should be over 100 per cent, which is, to say the least, doubtful.

There is, however, one statement in the paper which will for a certainty be accepted without reservation, namely, that the author has preached the advantages of a-c arc welding for 26 years. In view of Mr. Holslag's statement that the acceptance of the a-c arc has now become universal, it would seem that the endless repetition in the paper of arguments which have become not only familiar, but threadbare, through 26 years of preaching, should be superfluous.

Perhaps the acceptance of the a-c arc has not been so universal as this statement asserts. Indeed, what follows immediately

tacitly implies that such is not the case. The question is asked, "Why has a-c arc-welding progress been so retarded?" Mr. Holslag answers that the chief reason is the high open-circuit voltage, which lowers the power factor and is liable to cause nervous shocks, especially in wet places.

In the following two paragraphs Mr. Holslag gives a hint of what might have been an interesting topic for an engineering paper, namely, a method he has recently developed for overcoming the drawback to a-c welding just mentioned. The description is, however, entirely too inadequate for anyone to form an intelligent conception of its operation, let alone judge its merits. Had the paper omitted the great deal of needless repetition of old arguments and concentrated on an engineering discussion of this new development, it might have been a good one.

Mr. Holslag states that in Europe progress in a-c welding has preceded ours. C. H. Jennings, research engineer of the Westinghouse company, has recently returned from Europe where he spent considerable time studying various phases of welding. He has written at least one article and given a number of addresses on various phases of European welding practice. In Germany he found that the d-c arc preponderates, undoubtedly because of the great use of bare electrodes still prevalent there. The situation in England is interesting.

According to Mr. Jennings, the use of coated electrodes became prevalent in England at the very inception of the metallic arc-welding process. Furthermore, the strict requirements regarding inrush currents of induction motors made starting equipment expensive and militated against the use of motor generator sets. Hence, the conditions were ideal for a-c welding, and that is about all there was at the beginning. Some years ago, however, enough d-c welding had developed here to make the ratio about 20 per cent direct current to 80 per cent alternating current. The continued increasing use of direct current has made that ratio at the present time 40 per cent direct current to 60 per cent alternating current, and Mr. Jennings estimates that continuance of the present trend will shortly make it a 50-50 ratio. What will happen after that is problematical. If Great Britain possessed an ardent advocate of d-c welding, who had been preaching its advantages for a quarter of a century, he would now undoubtedly be prepared to publish a paper on "The D-C Arc Progresses."

Recently, when Mr. Jennings addressed the Milwaukee section of the American Welding Society on this subject, he was asked if he could account for this rapid increase of d-c welding in England. His answer was that the inability of the a-c arc to weld successfully nonferrous metals, such as aluminum, copper, copper alloys, nickel, nickel alloys, nickel clad steel, etc., and the superiority of the d-c arc in welding of some alloy steels and in vertical and overhead welding, are unquestionably factors in this changing ratio of d-c to a-c welding in England. Even Mr. Holslag concedes that d-c welding has these advantages, and for that reason gives it a lease of life, although only a tentative one.

There is one other statement in the paper that I in general agree with, although not 100 per cent. In his concluding paragraph Mr. Holslag says that alternating current has become the steam shovel of welding. It is well known, however, that the steam shovel has become an entirely antiquated piece of machinery, having completely given way to the internal combustion engine, that is, the gasoline or Diesel engine, and to some extent to the electric-driven shovel. Mr. Holslag did well in choosing an analogy, although I would not go so far as he does and compare a-c welding with the steam shovel, which is a completely outmoded piece of equipment. That is entirely unfair to a-c welding. There is, however, one strong similarity. If a steam shovel today were to be taken in trade for an up-to-date machine, its trade-in value would approach the vanishing point. It has been our experience that the same holds true when we are confronted with the situation of taking a welding transformer in trade for a motor generator set.

W. Richter (A. O. Smith Corporation, Milwaukee, Wis.): This discussion is confined to an analysis of the so-called "basic buck-back circuit" as shown in figure 2 of the paper.

For the purpose of studying the behavior of the circuit, replace the arc by a variable

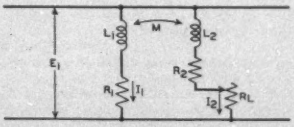


Figure 1

load resistance and the transformer by two coils, having self- and mutual inductance, as shown in figure 1 of this discussion.

Let

$z_1 = R_1 + jwL_1$ = primary impedance
$z_2 = R_2 + jwL_2$ = secondary impedance
$x = wM$ = mutual impedance
R_L = load resistance
E_1 = primary voltage
E_2 = secondary voltage
I_1 = primary current
I_2 = secondary or load current

We have then:

$$E_1 = I_1 \times z_1 + I_2 jx$$
$$E_1 = I_1 \times jx + I_2 \times (z_2 + R_L)$$

Eliminating I_1, results in

$$I_2 = E_1 \times \frac{z_1 - jx}{z_1(z_2 + R_L) + x^2}$$
$$= E_1 \times \frac{(z_1 - jx)/z_1}{z_2 + \frac{x^2}{z_1} + R_L}$$

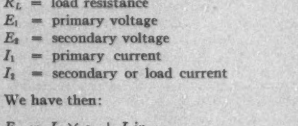


Figure 2

The secondary voltage is found by multiplying I_2 with R_L. This results in

$$E_2 = I_2 \times R_L = \frac{E_1 \times \frac{(z_1 - jx)}{Z_1}}{1 + \left(z_2 + \frac{x^2}{z_1}\right)/R_L}$$

For $R_L = \infty$ we obtain the open-circuit secondary voltage

$$E_{2o} = E_1 \times \frac{z_1 - jx}{z_1}$$

Putting this into the equation for I_2, we obtain

$$I_2 = \frac{E_{2o}}{z_2 + \frac{x^2}{z_1} + R_L}$$

This shows that the secondary current is the same as if we employed a generator or transformer with a terminal voltage E_{2o} and a fixed impedance $z_2 + (x^2/z_1)$ in series with the load as shown in figure 2 of this discussion.

Thomas M. Hunter (American Transformer Company, Newark, N. J.): Mr Holslag's paper is of considerable interest to the welding industry because it describes a number of circuits for improvement in a-c welding. Up until the present time direct current has been largely used for arc welding and alternating current has been used to a lesser extent. Economically alternating current has many advantages over direct current. The reasons for this are as follows:

1. The load factor on the average welding machine is very low and the difference between the running-light losses of a generator and transformer is very high, consequently the operating efficiency of the transformer is very much greater than the generator.

2. The maintenance cost of transformers is negligible as compared with generators.

3. Transformers can be built so that they are much easier to install and transport from time to time than is the case of generators.

The reasons why a-c welding has not been more generally used are as follows:

1. The transformers, as built up to the present time, have open-circuit voltages from 80 to 105 and this has been considered dangerous by many users of welding equipment.

2. The power factor of these transformers is very low, ranging from 20 per cent to 50 per cent lagging.

3. These transformers draw a very large single-phase current and due to the low power factor this affects adversely the line voltage which causes disturbance on other apparatus.

4. In many of the transformer designs the means of controlling current has been awkward and very unsatisfactory from the operating standpoint.

5. Due to the very high reactance of transformers the length of secondary leads has affected the current output to such an extent it was impossible to obtain desired currents at great distances from the transformer.

In Mr. Holslag's paper he shows a number of circuits which tend to overcome these objections. Figure 2 will lower the open-circuit voltage and afford satisfactory welding operation but it does not improve the power factor. In figures 3, 6, and 7 he shows the use of capacitors which do aid in improving power factor as well as lower the open-circuit voltage; in figure 7 a circuit

is shown where reactance and capacity is used in series with the secondary circuit of the transformer. This gives very desirable characteristics for arc welding. The capacitors are not in the circuit at no load and are introduced into the circuit in such a manner that there is no tendency for instability, dangerous voltages, etc., and the apparatus is quite simple. Therefore, it is possible to obtain operating characteristics as shown in the data given hereinafter. We are giving data on both a reactance transformer and a resonant-circuit transformer.

A. U. Welch, in his discussion, explains the action of this circuit and I believe his explanation is about what takes place. The welding current builds up voltages across the capacitance and the reactance higher than the impressed voltage and the arc is stabilized due to the fact that the open-circuit voltage and reactance voltage come into play just at the correct moment to maintain the arc. This of course means that a lower voltage can be used at open circuit and still maintain arc stability at least equal to that obtained with reactance transformers. There have been a great many devices offered for lowering this open-circuit voltage and the ones used in the past have been of a mechanical nature such as contactors. This circuit gives a result which is entirely automatic and requires no moving parts.

The control is designed so that a range of current from 20 per cent to 100 per cent

Table I

Test	Reactance Transformer	Capacitor Transformer
Drop in line voltage when thrown on line (per cent)	15	0
Power factor (per cent)	51 lagging	88 leading
Time required to obtain complete range in current	2 minutes	10 seconds
Change in current when secondary leads were increased from 60 foot length to 350 feet (per cent drop)	35	20
Current drawn on primary (amperes)	120	65
Open-circuit voltage on the secondary (volts)	83/105	64
Electrical efficiency (per cent)	88	87

can be obtained with stability throughout. The circuits are so interlocked that it is impossible to get complete resonance which would build up excessive voltages. The control is very simple requiring only a relatively few seconds to change from maximum to minimum or vice versa. It is made either for installation in the transformer or external, in which case it can be installed at a distant point. In many installations it is desirable to have the welding transformer installed on the balcony or some other place so as to conserve floor space and the control unit, being relatively small, can be installed near the operator, the interconnecting wires being of low capacity requirements. In this respect this control duplicates the practical results of a generator control. It is a very simple matter to make the control device motor operated.

Comparative tests of the capacitor control transformer versus the reactance control, 500-ampere capacity in both cases, give the data in table I of this discussion. In making these tests, a circuit of 150-kva capacity, 440 volts, 60 cycles, was used. All data given were taken at 500 amperes output from the secondary.

Summing up, I would like to refer to a statement made by Mr. Welch which I quote as follows:

> The adjustable-reactance welding transformer which is the accepted standard equipment for a-c arc welding has the advantages over the circuits presented in this paper of simplicity, low cost, low maintenance, adaptability, and freedom from overvoltages and other dangerous phenomena.

In my opinion no device is accepted as standard when better equipment is available. The comparative data given here fully justify the consideration of the resonant circuit for arc welding particularly when these advantages can be had with no sacrifice in operating characteristics.

Claude J. Holslag: The leading electric-welding companies in this country have fought the acceptance of the truth that the combination of a-c transformer welding and covered electrodes was and is the greatest advance in metal construction in its entire history. The large welding manufacturers made a concerted effort to stifle this advance to the art. The kindest thing I can say is they were innocent of the advantages to this country of this combination. The General Electric Company is apparently following the same policy in regard to the low-voltage developments and multiple star system. I notice Mr. Hansen is still of the d-c opinion that prevailed a decade ago. I would like to call his attention to the fact that even the Lincoln company has been attempting to sell a revolving a-c welder for the last five years and is now announcing a static transformer welder and, hence, friend Hansen is the last of the d-c "die hards."

The statement is made in the discussion of my paper that our multiple star system is not different from a grouping of single operator sets. In regard to this, I would like to refer to a three-page article in the April 1938 *Welding Engineer* which was written without my knowledge by Messrs. McGuire and Wood, president and general manager, respectively, of the Hamler Boiler and Tank Company, Chicago, where a 7,200-ampere installation was made by our company. We are listing a summary as made by another large company.

MULTIPLE-STAR-SYSTEM COMPARISON TABLE WITH OTHER ARC-WELDING EQUIPMENT

Versus A-C Single Arc Sets

1. Initial cost less
2. No voltage-drop interference
3.* Better load factor
4. Planned system; no overloaded circuits
5. Balance of phase load

Versus D-C Single Arc Sets

1. Initial cost less
2. Consumes less power—no idle loss—more efficient
3.* Advantage of load factor
4. Planned system with no overloaded circuits
5. Uses common ground

Versus D-C Multiple Arc System

1. Initial cost less
2. Consumes less power—no idle loss—more efficient
3. No interference of operators
4. Open circuit not fixed, but is arranged for adjustment

* Under better load factor, I would like to add the explanation that with single operator sets it is certainly obvious that if a fraction of their capacity is used for welding the rest of their capacity is not available but with the multiple star system half of the unused capacity of, say, two single operator sets could be added to create a third welding station. It is our actual experience that the capacity of this system is doubled because of this fact.

In regard to the reference that a man came back from Germany, who saw bare wire and d-c welding, this is due to one reason, namely; they dislike England and England's advance in welding with covered wire. However, for the last ten years, covered wires have been permeating Germany from all directions. Our Holland and our Scandinavian agents advise they have been having great success with alternating current and covered electrodes for the last ten years all over Europe, especially in Germany. Any person who could not see the advantages of covered wire now would be obtuse, indeed.

So as not to smother this triumph with words I will just point out that the exception noted in Mr. Hunter's discussion is the reactance means of controlling the current, which this company has developed, by which any amount of current can be varied from 10 per cent to 100 per cent with no greater power required under load than open circuit. Comparing this to, say, reactance controls which require two arms of a strong man to open and a very heavy motor for remote control and with which scheme it is practically impossible to move under load, I am quoting Doctor Comfort A. Adams that he cannot understand why the electrical industry has missed such a simple electromagnetic mechanical current-varying solution as we have developed.

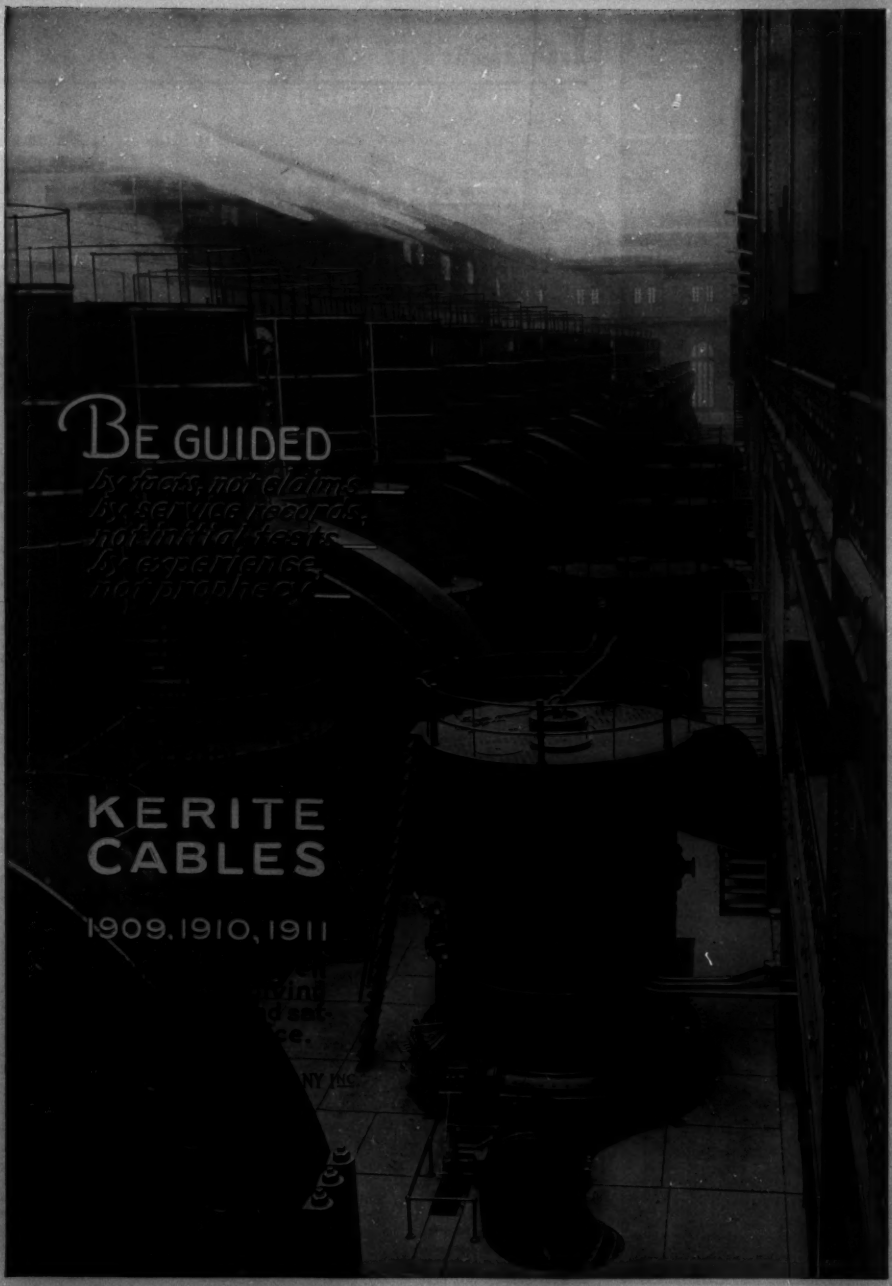
Although Mr. Richter presents a very simple and interesting analysis of my basic buck-back transformer, the method which he employs is wholly unsatisfactory for power transformers and was abandoned many years ago as far as that application was concerned. The reason for this abandonment was that this method involved a determination of a relatively small quantity by the difference between two relatively large quantities, both of which were hypothetical and widely variable.

In other words, L_1, L_2, and M as used in Mr. Richter's discussion are all widely variable.

If Mr. Richter's conclusion is correct, to the effect that this arrangement works the same as would a simple leaky welding transformer with an open-circuit voltage equal to E_{20}, it is obvious that this arrangement has no advantage. That this conclusion is not correct is obvious from the following fact: A welding transformer with an open-circuit voltage of 45 or 50 will not maintain a stable arc, whereas my buck-back transformer with an open-circuit voltage of 45 or 50 does maintain a stable arc.

The explanation of this fact is not obvious, but may be due to some short-time transient effect, the analysis of which is too difficult for me to tackle.

If the problem were as simple as Mr. Richter seems to think, it would have been solved long ago.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TRANSFORMERS

Industrial Notes

More Diesel-Electric Busses for New York.—With the addition of forty busses, 30 to be delivered this month and 10 in August, the Surface Transportation Co., of New York City, is enlarging its diesel-electric fleet to 83 vehicles. Motor and generator equipment for 30 of the new busses will be furnished by the General Electric Co. The transit company began trial operation with two such busses in 1937, all of which are of the 40-passenger type.

Norma-Hoffmann Elects Officers.—At a recent meeting, the board of directors of the Norma-Hoffmann Bearings Corporation elected the following officers: W. M. Nones, chairman of the board, O. P. Wilson, president and treasurer, H. J. Ritter, vice-president and secretary, C. B. Malone, vice-president in charge of plant operations.

Hasler-Tel to New Quarters.—The Hasler-Tel Company, sole distributors in the United States for Hasler speed indicators, has moved from 461 Eighth Ave., to 30 Vesey St., New York City.

Roebling Appointment.—The John A. Roebling's Sons Co., Trenton, N. J., manufacturers of wire and wire rope, insulated wires and cables, and wire cloth and netting, has appointed Earl N. Graf as manager of its Pittsburgh branch, located at 855 West North Ave.

Trade Literature

Fluorescent Lamps.—Bulletin, 16 pp., "Engineering Data on Fluorescent Lamps." Covers lamp operating data, performance factors, auxiliaries, operating characteristics and applications. Nela Park Engg. Dept., General Electric Co., Cleveland, O.

Alternator Voltage Regulator.—Bulletin 5651. Describes a new alternator voltage regulator of automatic, rheostatic type. The new commutating unit and contact bar makes it possible to regulate synchronous generators up to 2000 kva, 3-phase, 60-cycles. Ward Leonard Electric Co., Mount Vernon, N. Y.

Electric Tools.—Catalog, 48 pp. Describes a complete line of Thor portable electric tools, including drills, stands, screw drivers, tappers, saws, hammers, grinders, etc. Operations are illustrated. Independent Pneumatic Tool Co., 600 West Jackson Blvd., Chicago.

Steel Enclosed Switchgear.—Bulletin, GEA 3143, 32 pp. Describes type FH breakers, shipped assembled in metal cells, with the rest of the associated circuit equipment located elsewhere; and the FH cubicle, with the breaker and other switching equipment all factory-assembled in a metal housing. General Electric Co., Schenectady, N. Y.

Insulating Materials.—Catalog 11, 56 pp. Describes mica products, insulating papers and cloths, varnishes, fiberglas, tubing and sleeving, tapes, etc. Prices are included. Insulation Manufacturers Corp., 565 West Washington Blvd., Chicago.

Megohmmeter.—Bulletin 173, 4 pp. Describes model DM "Megohmer," with triple color grading scale, for classifying insulation. Herman H. Sticht & Co., 27 Park Place, New York City.

Wire Measuring Machines.—Cat. Sec. 3, 6 pp. Describes an enlarged line of counting machines for lineal measurement of both bare and insulated wire and cable, lead covered and armored cable, twisted pairs, etc. Durant Manufacturing Co., Milwaukee, Wis.

Rubber Insulated Cables.—Catalog C-42, 56 pp. Describes rubber insulated power cables; covers physical and electrical characteristics for all types and has a complete section on coding details of control cables. Technical data, including new tables on current carrying capacity, are included. Anaconda Wire & Cable Co., 25 Broadway, New York City.

Control Relays.—Cat. 12, 4 pp. Describes type C control relays applicable between the contacts of a control switch or push button and the circuit breaker or other apparatus to be controlled when the current-carrying or interrupting capacity of the switch or push button is less than the current required by the apparatus to be regulated. Roller-Smith Co., Bethlehem, Pa.

Plastics.—Catalog, 82 pp. A comprehensive, pocket-size handbook on "Plaskon" including complete technical data. Sections are devoted to principles of design, molding technique, properties of the materials and physical constants, electrical applications, etc., illustrated with graphs, tables, and photographs. Plaskon Co., Inc., Toledo, Ohio.

Belting.—Bulletin M9332, 36 pp. Describes a complete line of transmission and conveyor belts; installations in many industries are illustrated. Included is much technical information on belt selection, and data on speed, pulley size, tension, etc., and descriptions of numerous types of transmission drives and conveyor layouts. Mech. Goods Div., United States Rubber Co., 1790 Broadway, New York City.

Voltage Controllers.—Bulletin 424C, 4 pp. Describes various types of the "Variac," (for voltage control)—essentially an autotransformer consisting of a single winding on a toroidally-shaped core. Contact between the winding and the load circuit is made through a carbon brush which covers at least one turn of wire at all times; output voltages are continuously variable with perfect smoothness. General Radio Co., Cambridge, Mass.

Another central station installs AIR SWITCHGEAR for 2300-volt auxiliaries

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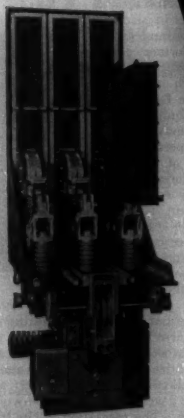


One of the 14 truck-type circuit breakers from the central station switchboard shown above. Two arc-shute barriers have been removed.

The electrical industry, including public utility companies and industrial plants, has given the very best kind of approval to I-T-E AIR SWITCHGEAR for 2500-5000 volt circuits. The approval is in the form of orders.

I·T·E CIRCUIT BREAKER CO., PHILADELPHIA, PA.

New Products

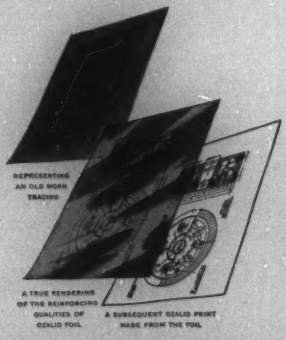
Signaling Transformers.—A new line of heavy duty type signaling transformers has been announced by The Acme Electric & Mfg. Co., Cleveland. These units are particularly advantageous for applications that require unvarying operating characteristics

under continuous performance. For the conversion of 115-volt primary to 4-, 8-, 12-, 16-, 20- or 24-volt, low voltage supply for the operation of bells, sirens, signaling systems, relays, control systems, etc., these transformers are said to offer greater reliability. High silicon, low-loss steel cores, assembled with machine wound, vacuum impregnated, hand finished coils are completely sealed in compound that is unaffected by high room temperatures, moisture or cold. The black enameled, rust resisting case, includes integral outlet box compartments for primary and secondary connection. Knockouts provide for conduit or armored cable. Designed to meet Underwriters specifications, the transformers are available in 50-, 100-, 250-, 500-, and 750-va capacity.

Communication Circuit Test Set.—A new convenience has been built into the versatile type U test set used generally for cable fault

location in signal and communication circuits, by the Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia, Pa. To permit use of the self-contained galvanometer with the Hilborn loop, a switch position has been added. Because of its greater accuracy, the Hilborn loop is used for quickly locating faults in cable sections, particularly in metropolitan areas. Where no other test wires are available, the general practise is to roll out a test pair, using one conductor for the good return, the other for the galvanometer. All speed, flexibility, accuracy and self-contained portability of the previous design have been retained. A shoulder strap added to the leather case, holds the test set in convenient carrying or operating position.

Light Sensitive Foil.—Short cuts in drafting and technical reproduction are affected by a new sensitized foil recently announced by the Ozalid Corporation, 354 Fourth Ave., New York. This foil is supplied in two weights, each having a different finish. Illustrated are the reinforcing qualities of the clear foil in intensifying and strengthening the lines of a print made from a foil duplicate of an old, soiled and faded tracing. This supersensitive foil develops an exceedingly opaque sepia line which has exceptional covering power, and Ozalid whiteprints made from this foil duplicate are sharper and much easier to read than the original tracing. As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A TRUE RENDERING OF THE REINFORCING QUALITIES OF OZALID FOIL
A SUBSEQUENT OZALID PRINT MADE FROM THE FOIL

a result, it is possible to reclaim old, soiled and worn original drawings which heretofore have been considered unserviceable. This clear foil is also in demand as a substitute for an original drawing when duplicate originals are needed. It likewise serves as a fast-printing substitute for a slow printing original when speed in production of paper prints is desired.

One-Piece Cast Rotor.—A new one-piece, centrifugally cast "Copperspun" rotor has been developed by Fairbanks, Morse & Co., Chicago. The rotor winding is made of pure copper. The rotor bars and end rings are formed in one piece by pouring molten copper into a mold that encases the punched laminations, stacked and held under pressure. Copper is poured from one end only as the entire assembly is spun at high speed. The opposite end ring is formed by material that has passed through the rotor slots insuring a fluid material during the casting process. As a result of the centrifugal force,

a tough, dense, ductile copper winding is produced with high strength, full slots and uniform structure and conductivity. After completion of the centrifugal casting of the one-piece copper winding, the rotor is machine finished over all surfaces. Specially designed fans have also been developed for this new rotor, which is especially adapted to severe service such as plugging or reversing duty, which demands greater mechanical strength at abnormal temperatures.

Constant Voltage Transformer.—The new constant voltage transformer introduced by the Sola Electric Co., 2525 Clybourn Ave., Chicago, Ill., assures a dependable source of perfectly regulated alternating current, according to the manufacturer. It is unaffected by line transients or chronic high or low voltages, is smaller in size and more compact. The transformer comes in a price range low enough to permit its use for production equipment applications. Among the operating features of this new transformer is its ability to maintain constant output voltage to within ±1 per cent, from any input within the specified limits; its uniformly high input power factor—above 90 per cent throughout the entire operating range; its low harmonic content, assuring practically no distortion of output wave form over the entire operating range; and its high over-all efficiency, which closely approaches that of a well designed, double-wound transformer. The regulation of the transformer is automatic, instantaneous and continuous. There are no moving parts and nothing to adjust, and neither maintenance nor replacements are required. Both the transformer and its associated circuits are protected against damage by accidental short circuits.

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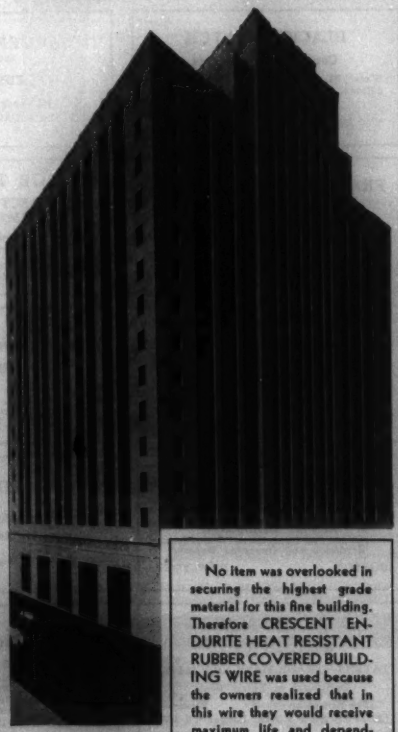

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Employment Bulletin

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E.E., 32, married; 10 yrs exper: Des and field engg for control and protective relay systems; supervising maintenance automatic substations; GE test, service engg. Desires asst engg pos. E-478.

E.E., 1921, Prof License NJ; 5 yrs indus engr, estimates, reports, des, devpmt; 11 yrs des engr, central station and substation. Foreign language: German. E-479.

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ASST E.E., 31, married; 5½ yrs at NYU, 6 yrs testg, inspection and supervision. Capable des small precision mechanisms. Some draftg. Desires pos with engg future. E-481.

B.E.E., Pratt Inst, 1938, 25, single; 2 yrs lab asst, 4 mos substation maintenance, 6 mos inspection transm and distr lines, radio exper. E-472.

B.S.E.E., Drexel Inst, June 1939, single, 23. Specialized pwr and radio engg; 2 yrs co-operative RCA. One yr pub util. Desires pos jr engr with advancement, location immaterial, salary secondary, available immed. E-475.

B.S.E.E., M.A.E.E., '37, Columbia, single, 27; 4 yrs pub util constr, gen wiring; one yr office engr; 2 yrs lab asst, Columbia; 9 mos trade sch course. Excellent ref. N. Y., Cal. E-482.

M.S.E.E., 1939, single, 28; B.S. 1932. Exper: 5 yrs gen business, 16 mos Westinghouse generator test. Desires work as jr engr; constr. mfg or util co. E-483.

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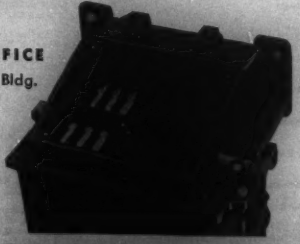

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General Electric Co., Schenectady, N. Y.
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General Electric Co., Schenectady, N. Y.
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General Electric Co., Schenectady, N. Y.
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General Cable Corp., New York
Roebling's Sons Co., John A., Trenton, N. J.

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Copperweld Steel Co., Glassport, Pa.
General Cable Corp., New York

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Crescent Ins. Wire & Cable Co., Trenton, N. J.
General Cable Corp., New York
General Electric Co., Schenectady, N. Y.
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General Cable Corp., New York
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Kerite Ins. Wire & Cable Co., New York
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Okonite-Callender Cable Co., Passaic, N. J.
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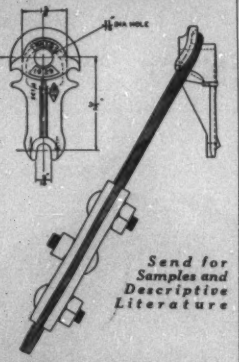

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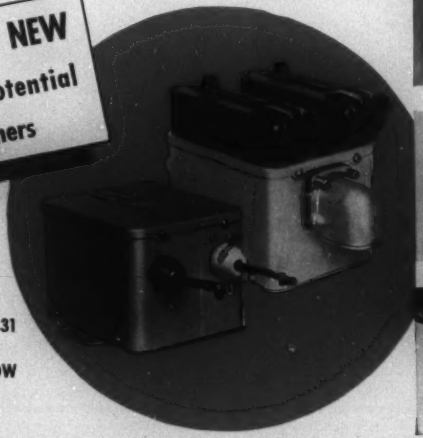

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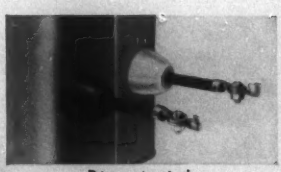

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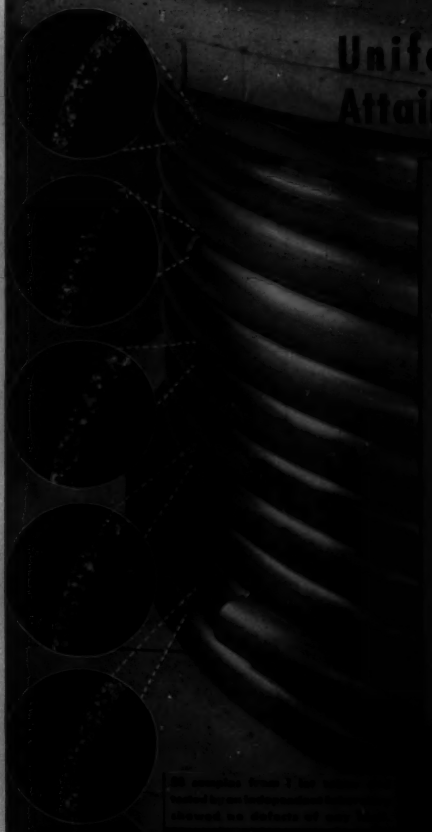

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